SOCIAL DIMENSIONS OF THE ECOLOGICAL CONCEPT OF RESILIENCE

By

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To my parents.

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This dissertation is a waypoint, not a destination, on my intellectual path. I would be remiss not to thank the guides who helped me this far. As an advisor, Clyde Kiker has constantly prevented me from being trapped in narrow disciplinary confines, and as a friend he has encouraged and supported me. I thank my supervisory committee (Steve Sanderson, Jeff Burkhardt, and Chris Andrew) for their help in and out of the classroom. Years of working with Steve Sanderson have taught me that the obvious intellectual questions are never the best ones.

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TABLE OF CONTENTS

page

ACKNOWLEDGMENTS iv

LIST OF TABLES vii

LIST OF FIGURES viii

ABSTRACT ix

INTRODUCTION 1

Environmental Uncertainty and Human Behavior 2
Traditional Economic Analysis 3
Organization of the Dissertation 6
Path Dependence and Multiple Equilibria in Economics 6
Individual and Collective Conservatism 6
Political Economy of Resilience 7

LITERATURE OVERVIEW: SOCIAL INTERACTIONS IN COMPLEX ENVIRONMENTS 9

Scales of Processes, Driving Forces, and Analysis 9
Increasing Returns, Path Dependence and Resilience 12
Technological Choice 13
Location Choice 13
Illustrative Example: A Standard Polya Process 13
Causes and Results of Network Externalities 16
Limitations of Path Dependence Approach 17
Other Examples of Path Dependence 18
Boom and Bust Literature 18
Punctuated Equilibria 19
Human Response to Multiple Equilibria 19
When Do Multiple Equilibria Matter? 20
What Predominates, History or Expectations? 20
How to Control Path Dependence: Intervention or Coordination? 22
Adapting to Equilibrium 23
Escape from Lock-in 23
Bounded Rationality 24

INDIVIDUAL AND COLLECTIVE CONSERVATISM 26

Flexibility and Rigidity 26
Reliability Theory 26
Collective Conservatism 31
Dual Preferences 31

Spatial Version of Kuran model 39
Spatial Model Discussion 45
Conclusion 46

POLITICAL ECONOMY OF RESILIENCE 48

The "Old Ecology" 48
The "New Ecology": Upsetting the Balance of Nature 51
"Change is the Only Constant" 52
"All Ecology is Local" 52
"We Are Everywhere" 53
Beyond the New Ecology: Tools for Understanding 56
Moderately Complex Models of Ecosystems 56
New Ecology Revised 57
Implications of the "New Ecology" for Natural Resource Management 64
Toward a Political Understanding 68
Politics with a Small "p" 69
The Problem of Fit 70
Optimal Scales of Management 71
Cross-scale Management or Nested Scales 72
Science by Consensus 73
Scale and Scope Mismatches 75
Open Systems 77
Politics with a Capital "P": Political Economy of Resilience 80
Homogeneity of Actors 81
Distribution 82
Power 83
Hierarchies of Power 87
Understanding Uncertainty 90
Conclusions 93

CONCLUSIONS 94

Cycles of Salience 95
Role of History 95
The Revival of Narrative 97
People, Ecosystems, and Resilience 99

APPENDIX A *MATHEMATICA* CODE FOR THE STANDARD POLYA PROCESS 101

APPENDIX B *MATHEMATICA* CODE FOR THE DUAL BELIEF MODEL IN SPACE 102

LIST OF REFERENCES 105

BIOGRAPHICAL SKETCH 116

LIST OF TABLES

Table page

1. Mechanisms of environmental influence on social processes 3

2. Wiener's four faces of environmental law 55

3. Comparing the old ecology and two versions of new ecology. 58

4. Consideration of scales in scientific explanation 60

5. The four cultures of "cultural theory" 63

6. Economics and politics as method and substance 70

7. Hierarchical ecosystem responses to perturbation 73

LIST OF FIGURES

Figure page

1. Law of large numbers with a fair coin 14

2. Visualization of an urn process. In this case, there are 5 red balls and 4 green balls. The probability of drawing a red ball on the next trial is 5/9. $p_r=r/(r+g)$ 15

3. Ten runs (98 trials each) of a standard Polya process. 15

4: Propagation curve with social interaction 34

5. Propagation curves for hard, soft, and mixed knowledge systems 37

6. The Moore[1] neighborhood 41

7. Propagation curve for simulation example 42

8. Results of simulation with varying neighborhood sizes from 9 to 121 (the whole population), with an announced initial opposition of five percent, and with the threshold distribution from Figure 7. 43

9. Histograms for each of four Moore neighborhoods from the previous simulation. N is the number of agents revolting, Freq is the frequency 44

10. Holling's four views of nature 61

11. Mary Douglas's four cultures. *Group* describes the degree of collectivization, and *grid* describes the degree of social structure (typically inequality). 63

12. The four periods in the "adaptive ecosystem cycle." From Figure 1.2 of Holling 1995 64

13. Scale-varying properties of management systems 75

14. Steps 2-7 of a Polya distribution game. Shaded triangles show Pareto-safe areas remaining after each step. 84

15. Ten realizations of a Polya 25-step distribution game 85

Abstract of Dissertation Presented to the Graduate School
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The consequences for social systems of recent innovations in ecological theory are examined. Economic models that address issues of path dependence, multiple equilibria, boom and bust, and increasing returns are reviewed, and are used to highlight parallel concepts and useful bridges to ecological literature. Existing models of path dependence are frequently incomplete in that they do not address the dynamics of escape from lock-in, nor do they rigorously model the problem of human responses to multiple equilibria when there are welfare losses at stake. Many of the models use the concept of bounded rationality to understand the complexities of human behavior.

Despite the subtleties of managing complicated resource systems, human behavior is often rigid and conservative, while ecologists and economists suggest that it should be flexible and adaptive. Reliability theory is used to examine the consequences of a competence-difficulty gap between the ability of agents to choose management actions for particular situations and the level of uncertainty they face in recognizing those situations when they arise. It is found that rigid behavior may outcompete flexible behavior under certain conditions.

In uncertain environments, people rely on the opinions and knowledge of others to supplement their own incomplete knowledge or to substantiate or invalidate their beliefs. When social proof is important in

determining beliefs, a dual belief model is useful in sudden shifts in public opinion. People hold beliefs privately, and they express them publicly if they believe they will be supported by public opinion. Otherwise, they may suppress or falsify their private beliefs. When people estimate public opinion by relying on those closest to them (in their local neighborhood) instead of in the public at large, there can be a wide variety of equilibria for public opinion.

Moderately complex theories about ecosystem structure and function stress the importance of spatial and temporal patterns of change at multiple scales, and permit a diversity of views about the relationship between humans and nature. This creates a set of problems for institutional design, and opens up opportunities for political maneuvering and strategizing, particularly when the distribution of gains from institutional change are unequally distributed. Because there is a wide range of beliefs which are compatible with ecological realities, the social construction of ecological crisis is as important for institutional change as are objective measures of crisis.

INTRODUCTION

Ecological resilience can be defined in a number of ways. Resistance to change is one way; speed of recovery from disturbance is another. These definitions are restricted in scope to systems with a single, global equilibrium. Holling has proposed that "resilience" be used to describe the ability of systems to recover from disturbance *at all* (Holling 1973). This definition supposes that there is at least one alternate state into which an ecological system can move, and that it may not recover its former state easily; the definition is only meaningful for systems with multiple equilibria. Examples include lakes that flip from clear to green (Carpenter and Cottingham 1997) and rangelands which flip into thorny scrublands (Walker 1995).

Recognition of the existence of multiple equilibria in ecological systems has implications for ecological management. The ecological concept of resilience derives from a fundamental revision in the way ecosystems are viewed. As is so often the case, a revolution in one discipline or area of knowledge has implications for others. The implications are both methodological and substantive.

Methodologically, the revolution in the way ecosystems are viewed is the lesson itself: the abandonment of static notions of single equilibria, gradual change, and strongly decoupled hierarchical scales may apply to social systems as well as ecological ones. The *general* revision of knowledge to include issues of *complexity* crosses disciplines and subjects, though not evenly or completely (Waldrop 1992, Holling and Sanderson 1996). Much of the next chapter examines recent attention in economics to issues which are quite general: the importance of history, self-organization, and path-dependence.

The substantive implications concern how the objective reality of ecosystems is understood. Social science theories about the interaction between humans and nature depend on how nature is modeled, and in a reflexive way, human behavior itself depends on how nature is modeled. If ecosystems are found to behave differently than was previously assumed, then theories about ecological management need to be re-examined.

The revision of ecological theory has substantive implications for politics as well. In the simplest sense, distributional concerns may be raised where multiple ecological equilibria have welfare implications. Moreover, multiple equilibria will make it difficult to choose between competing scientific hypotheses, increasing the political component of the construction and validation of knowledge. For example, the very possibility of a revision in scientific perspective raises the question of whether the "received wisdom" was systematically biased in favor of existing power structures. The stability of the previous system may be interpreted as self-reinforcement of the status quo for the material or academic benefit of a particular class, party, or school of thought.

Environmental Uncertainty and Human Behavior

The substantive implications of the concept of ecological resilience, and of the revision in ecological theory which lies behind it, have a social significance. Environmental uncertainty is a fundamental influence on human behavior. Anticipating, dreading, suffering, adapting to, and trying to modify risky environments has forever been a part of the human experience. For some, it is understood that the form of environmental uncertainty must influence the form of social interactions. Environmental determinists and cultural materialists would argue that it is one of the primary, strong determinants of social organization and culture; idealists might argue the opposite. By rejecting these antinomies, we are left with a weaker, but more interesting hypothesis: the form of environmental uncertainty influences, but does not determine, the form of social interactions.

Through what mechanisms might this influence find expression? There are three main pathways, which I call "tactical," "strategic," and "imaginary"[1] (see Table 1). The first pathway deals with issues of social organization "against" environment, where collective benefit is a sufficient justification for observed practices. What institutions or patterns of collective action, managed in what way and on what scale, tend to be adaptive or to "fit" with which forms of environmental uncertainty (Folke et al. 1998)? How do social interactions (coordination, competition, other institutions) assist in managing the environment? Do social interactions and social structures convey advantages that overcome constraints on

individuals, in terms of perception, effectiveness, and expectations? Much of the common property and indigenous knowledge literature tends toward this category of environmental influence on social interactions. This type lends itself toward evolutionary and, on occasion, functionalist theories.

The second pathway of environmental influence on social organization is by creating strategic space via differential payoffs, differential abilities to capture resource flows, and what they imply for social and political organization and stability (Knight 1992). How do social interactions convey economic or political power on certain players, and how does environmental management provide an arena for the expression of power? What effect do such strategic interactions have on environmental systems?

The third pathway is through environmental "imaginaries," in the terminology of Peet and Watts (1996). How much of the mythology (read "models") of the environment come from the environment itself, and how much is socially "constructed"? This thesis will deal mostly with the first two, and will deal with the third in the final section.

Table 1: Mechanisms of environmental influence on social processes

Mechanism	Goals and intentions	Constraints and opportunities
Tactical	fixed	fixed
Strategic	fixed	variable
Imaginary	variable	variable

Source: Jeff Burkhardt, personal communication

Traditional Economic Analysis

Economic analysis of environmental problems has proven to be a powerful tool for understanding human behavior in exploiting natural systems. Economic models, coupled with environmental or ecological models, have provided insight into problems as diverse as groundwater depletion, biodiversity loss, and global climate change. By drawing on ecological and other environmental theories, they have

[1] Names for the first two were suggested by Clyde Kiker.

been grounded in a usefully-simplified rendition of reality, while offering a rigorous description of rational actors confronting that reality.[2]

Outside the field of economics, however, models of rational actors responding to well-defined environmental change are met with less than universal acclaim.[3] Ecologists and ecosystem modelers harshly criticize the ecological assumptions that underlie many models of resource use, and political scientists, anthropologists, and sociologists criticize the versions of economic rationality they see in economic models. Many of the resultant discourses are fruitful in highlighting useful differences in perspective and theory between the disciplines. But how can the differences be used to generate understanding that will move the theory and practice of environmental management forward? Is it possible to incorporate more complex ecological dynamics and more sophisticated understandings of rationality into economic models?

More pointedly, how can economists model the behavior of social systems that are confronted with ecological processes that are varying on multiple scales? How can we account for fundamental ignorance about environmental risks, and how do we model individual, institutional, or social learning (if the latter two even exist)? What recommendations do we make about managing ecosystems that are subject to constant change, especially when there are multiple stakeholders using the resource and when the stakeholders have radically different mental models about the dynamics of the resource system? What hypotheses can we form about the nature of strategic interactions between stakeholder when the system may exhibit multiple stable states, or when the state dynamics of the system are themselves a topic of contention? What role do distributional concerns and political and economic power play in such systems?

As to methodology, two questions present themselves: (1) can such systems be modeled at all? and (2) can they be modeled in a believable way (such that other disciplines will find them accessible and enlightening)? The issue is how to create a set of models which are just complex enough to capture

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[2] Economist Robert Walker (personal communication) once described the human behavior he saw in purely ecological models as that of "demented apes wrecking their environment according to simple differential equations."

[3] Models may not meet with much acclaim within economics either. Deirdre McCloskey, for example, showed scant appreciation for the proofs of "blackboard economics" in her recent book (McCloskey 1996).

interesting ecological dynamics, and combine them with economic models which are just complex enough to describe interesting social dynamics. It is doubtful that deductive, analytical, and theoretically rigorous mathematical models will suffice, due to either intractability or the debilitating nature of necessary simplifying assumptions.[4] Even when tractable, such models may too often end up speaking only to economists. Inductive models, while useful for discovering patterns, too quickly degenerate into either too-detailed narrative or "just-so" stories. While I will make the case in the conclusion to my dissertation that narrative is a valuable tool, thick description (Geertz 1973) by itself is not sufficient. Another way of asking economic questions is needed.

Robert Axelrod proposes that agent-based modeling is that third way (Axelrod 1997). As a "bottom-up approach" to modeling economic interactions (Epstein and Axtell 1996), in keeping with the spirit of complexity research, agent-based systems [5] are neither a detailed description of reality or a tool for prediction. In Axelrod's words, they may be thought of as an "aid to intuition" (1997:4), helping to demonstrate patterns which emerge from interacting entities. Some simulation models are quite complex portrayals of all the relevant dynamics in a system, but agent-based models will generally be much simpler. After all, if the point is to aid thinking about complex systems, it is necessary to be able to trace patterns back to initial conditions and model features. Agent-based models, therefore, may more usefully be described as *caricatures* of real social processes, that highlight key features in the same way that ecological mini-models capture some but not all important features of ecosystems.

By highlighting complex (or even simple) patterns that result from some simple assumptions, agent-based modeling takes a modest approach to social processes, which will emphasize and accentuate the contribution of other disciplines. Some social processes cannot be described by any mathematical model. By describing the ones we can, we can more usefully delineate the limits of economics, and the gaps in explanation that are left between disciplines.

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[4] Arthur et al. (1997:4) cite the following features of economic systems that present tractability problems in standard economics models: dispersed interaction, cross-cutting hierarchical organization, continual adaptation, perpetual novelty, and out-of-equilibrium dynamics.

[5] Agent-based models are also called interacting particle systems, decentralized models, artificial societies, or adaptive agents models.

Organization of the Dissertation

The three chapters in this dissertation were largely written at different times and for different purposes. Here I show how they relate to one another and how they touch on the general themes I have outlined above.

Path Dependence and Multiple Equilibria in Economics

As a background to this research and an overview of the literature, I have included much of a paper on evolutionary economics, multiple equilibria, path dependence and resilience that I wrote for the Resilience Network of the Beijer International Institute for Ecological Economics. That chapter looks at parallels between the adaptive cycle and the recent explosion of writing on path dependence in economic systems. The focus of this chapter is primarily on the methodological parallels between economics and ecology, and on the limitations of the path dependence approach (how lock-in but not escape-from-lock-in are explained).

Individual and Collective Conservatism

Two evolutionary economic models that describe sources of rigidity, conservatism, and surprise in social systems are described in more detail, and the implications of agent-based spatialization are shown for one. The two sections of this chapter explore both methodological affinities between ecology and economics, and of the substantive implications of environmental complexity for economic agents. The chapter coheres in the notion that agents are boundedly rational, and that in the absence of complete information and in the presence of cognitive limitations, agents may exhibit behavior that is inflexible or conservative. This can be understood as economizing on decision-making.

Rigidity and flexibility

The first part of the second chapter examines the issue of flexibility and rigidity in individual decision-making processes. The common critique of poor environmental management is that human-managed systems are simple while environmental systems are diverse and heterogeneous, or, slightly more

accurately, that there are incentives for humans to inappropriately simplify ecological systems. This chapter chiefly addresses the substantive implications of changes in environmental uncertainty on the decision-making process, and how prescriptions for increased flexibility in environmental management may ignore the issue of reliability in performing the right action at the right time. In particular, it offers a partial mechanism behind the escalation of rigidity in well-managed systems—what Stephen Sanderson calls the "Holling frustration" (personal communication).

Social proof and dual preferences

This part of the second chapter provides one of the clearest parallels from the social sciences of thinking about multiple stable states, the role of history, and a kind of resilience in social systems. It shows how public opinion on an issue may prove stable in the face of new information when agents are depending on other agents to validate their beliefs. Agents may have private beliefs or preferences about an issue, but their expectations of public opinion may influence their expression of their beliefs. Such *social proof* is an important aid to belief formation when private beliefs are weak or private information is limited, but it has political implications as well, as explained in the chapter below.

Political Economy of Resilience

The third chapter examines the social significance of new conceptions of environmental complexity, and their implication for the design, evolution, and exercise of political power.

Two views of ecology

This overview is an attempt at a critique of the recent changes in ecological perspectives on nature, and the way they have filtered into writing on economics, politics, environmental history, and environmental law. Each discipline puts a different spin on the implications of changes in ecological theory. This section outlines some of the most often-cited features of the new ecology.

The problem of fit

This section of the third chapter attempts to summarize and implicitly to critique some of the responses to the new ecology from a utilitarian perspective. Among the utilitarian perspectives can be

found two camps, utopians who have an underlying vision of harmony and sustainability and non-utopians who merely seek to construct a consequentialist calculus for judging the success of environmental management. They share the underlying perspective that good environmental management is a problem of finding the right "fit" with ecological systems. In Ruhl's words, "[t]o manage the impact of human society on the inherently chaotic, adaptive environment, the environmental law system must itself possess those dynamical qualities" (Ruhl 1997:940).

Politics of ecological resilience

This section is perhaps the most problematic; it also raises the issues least amenable to mathematical modeling. It is an attempt to respond to the infra-political approaches of the utilitarians, and to introduce notions of heterogeneity among agents, with a resultant conflict of distribution and the use of power in economic and social interactions.

LITERATURE OVERVIEW: SOCIAL INTERACTIONS IN COMPLEX ENVIRONMENTS[6]

There can be little doubt that the idea of a perfectly rational economic man operating in an environment with complete information and complete markets makes a useful null model for examining human behavior. There is likewise little doubt that such conditions are not even nearly approximated in many interesting cases. Much of the self-styled "heterodox" economic literature of the past two decades has taken as its mandate to attack the rational man assumption of neoclassical economics, but without advancing useful alternative models. Similarly, many have criticized the "static" nature of mainstream economics without pinpointing precisely where dynamics would help. However, a growing literature in economics has recently developed models of behavior that have clear linkage to the work on complexity inspired by what has been called the "new ecology" (Holling 1992; Botkin 1990); see also the chapter in this volume on the Political Economy of Resilience). This work is characterized best as evolutionary: Witt's definition (1993) of evolution as "the *self-transformation* over time of a system under investigation" (my italics), makes the contrast to traditional economics clear. In a neoclassical optimization framework, agents respond deterministically to changes in exogenous conditions, constraints, or driving forces. There is little consideration of change that is created by the agents themselves. Witt's objection is to the dichotomy between exogenous disturbances on the one hand and endogenous restorations of equilibrium states on the other (Witt 1993).

Scales of Processes, Driving Forces, and Analysis

In a short thought piece, Partha Dasgupta has pointed the way forward for a program of research that addresses slow and fast variables in economics, while maintaining the special contribution of economic

[6] This chapter borrows heavily from a background paper prepared for the 1997 Annual Meeting of the Resilience Network of the Beijer International Institute for Ecological Economics at Malilangwe, Zimbabwe.

theory: "If modern economics possesses a distinctive character, it is that it tries to discover the various pathways through which millions of decisions made by individual human beings can give rise to emergent features of communities and societies" (Dasgupta 1997). He further notes that modern economics has largely ignored questions of cross-scale interactions by limiting itself to short time periods at particular scales.

One way of structuring an inquiry into human social and economic processes at multiple scales is with a typology of response to surprise. Gunderson et al. (1997) have already proposed a three-fold typology of surprise, which not surprisingly have different types of responses.

Type I surprises are what Gunderson calls local surprises. They may be created by a narrow breadth of experience with a particular system, either temporally or spatially. Local surprises have a statistical distribution, and response to these surprises is to form subjective probabilities, and to use new information to update those probabilities in a Bayesian fashion (although following Heiner [1983, see below] we might guess that this is only appropriate for very simple environments). Based on these estimates, there are a wide range of adaptations to risk that are amenable to economic rationality on an individual level, including risk-reducing strategies and risk spreading or risk pooling across independent individuals. Type I surprises are manageable by individuals and associations of individuals. There is probably no collective action problem.

Adaptation-to-risk-strategies fail when surprises are not local, or when individuals are not independent. Type II surprises (Gunderson's panarchy surprises) occur when there are cross-scale interactions, such as when local variables coalesce to form a regional or global pattern, or when a process exhibits contagion (as with fire, insect outbreak, disease). Unintended consequences resulting from the action of many individual agents is a Type II surprise. Individual responses are not generally effective (although there are special cases—Coase's [1960] farmer and herder come to mind): instead individuals may act in concert, if appropriate institutions[7] are available or are readily formed (McKean 1996). One

[7] Institutions are emergent and durable patterns of behavior and ideas of the sets of individuals who maintain them, and an important influence on those individual characteristics which economists often take for granted (tastes and preferences, for individuals; organizational patterns and routines, for firms;

example, suggestive but not yet well-investigated, is a potential explanation for the recent, sudden increase in burning in the Brazilian Amazon. There are two kinds of externality for farmers using fire in the Amazon: in a survey by Robert Walker, a common complaint was the unwanted and ill-timed spread of fire from neighbors' plots, a negative externality. Stephen Vosti has suggested a positive externality of neighbors' burning: evasion of government regulators issuing citations for burning is easier with more fires burning at once. Each externality would indicate a benefit to synchronized burning, and this could be triggered by even slight climatic signal (a few wet years in which fuel accumulates, followed by a drier year with a higher payoff in burning) (Pritchard et al. 1998).

The final class of surprise by definition precludes prediction: Type III surprises comprise true novelty, never-before-experienced phenomena for which strict pre-adaptation is impossible. However, it may be possible that some systems cope with Type III surprises better than others, if they have developed mechanisms for reorganization, learning, and renewal. Type III surprises are especially useful in revealing latent processes which are undiscovered in "normal" times. As Hahn (1987) notes, "[t]here is a continuum of theories that agents can hold and act upon without ever encountering events which lead them to change their theories." Type III surprises may generate that kind of change, or at least reveal the latent mental models to researchers. Oliver Coomes has begun work with an Amazonian community whose blackwater (oligotrophic) tributary was captured by the main whitewater river in a single flood event which reconfigured the water course, and changed the nature of the fishery. He has been able to observe differential success in adaptation in different communities based on pre-flood patterns of organization which before had seemed unimportant (discussed in Sanderson and Pritchard 1997). But success in coping may have more to do with the timing of the surprise than with overall societal flexibility.

Mainstream, modern economics deals mostly with Type I surprises, although increasingly it is addressing Type II situations (endogenous growth theory, economic geographical problems, technological

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rules for exchange, for markets). They evolve over time, and thus have a characteristic time scale, and involve identifiable sets of individuals, and so have a (rough) correlate of spatial scale.

change, etc.).[8] Type II surprises have the potential to generate a cross-scale response. Most of the literature reviewed here deals with Type II surprises and suites of possible institutional responses.

Insurance is one way for dealing with certain kinds of uncertainty or local surprise. Some insurance and incentives are to encourage risk-taking, whereas for others risk-taking is an undesirable side-effect. An example of encouraging risk taking is when governments encourage or require risk averse farmers to plant high-yield, high-risk crops, using either penalties or tax policy. There are no situations in which insurance leads to conservatism.

The converse case is more complex. Where risk-minimization strategies are apparent, it is by no means necessarily for reasons of conservation or preservation. Richards suggests that the ecological reserves and risk-minimization strategies of African peasants could have more to do with avoiding "capture" by the colonial (or post-colonial) state than because peasant society coexisted in harmony with the land (Richards 1983:44).

Increasing Returns, Path Dependence and Resilience

One source of surprise in economics falls under the category of increasing returns. What Nicholas Kaldor identified in 1972 as "still a largely uncharted territory for the economist" (Kaldor 1972) is currently being mapped and settled by trade theorists, regional economists, endogenous growth theorists and students of technological change. Increasing returns in economic systems may have many causes; one is positive network externalities, in regional economic systems and in technological systems. Both have been modeled as population distribution phenomena (Nelson 1995)—one adds members to a population and allow them to distribute themselves among various categories (for example, which region to settle in, or what of two competing technologies to adopt).

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[8] Whenever a social planner is invoked, it is to address the "surprising" result that individual optimization does not result in a socially-efficient outcome. This is the bread-and-butter of resource economists, who have often treated a special sort of Type II "surprise"—situations where public and private costs diverge, public goods problems, congestion problems, etc. It should be noted that when an economic model invokes a social planner to demonstrate socially-efficient conditions, one should turn to reality to see if institutions have been evolved which achieve the same ends.

Technological Choice

Paul David's explanation for the persistence of the QWERTY keypad on typewriters, personal computers, and digital assistants (David 1985, 1997) has given the non-economic population insight into the results of network externalities, although the historical accuracy of his story has been questioned (Liebowitz and Margolis 1995a, 1995b, 1996). The controversy points to some of the difficulty of establishing evidence for network externalities and the attendant hypothesized historical effects (see below)[9]. David's model is based on history as a determining force in technological choice, as is Arthur's model of "information contagion" (Arthur and Lane 1994); other writers (such as Katz and Shapiro 1985) use a model of rational (fulfilled expectations) equilibrium.

Location Choice

Both Krugman (Krugman 1994) and Arthur (Arthur 1995) delineate models of location choice which exhibit dynamics of path dependence, although neither distinguish carefully between localization (same sector concentration) and urbanization (agglomeraton due to inter-sectoral linkages). [10] The point of both models is that network externalities cause path dependence in geographical patterns, which leads to concentration of economic activities unexplainable by deterministic geographic variables, and attributable at least partly to the role of chance or history.

Illustrative Example: A Standard Polya Process[11]

Most stochastic processes that we think of have outcomes with deterministic structures—means and standard deviations that are stable. For example, if a fair coin is tossed, although the immediate outcome cannot be predicted, the number of heads in a thousand tosses can be predicted with some certainty. After a large number of tosses, a structure emerges. Borel's strong law of large numbers ensures that repeated

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[9] There are clearly ideological criticisms of path dependence as well.

[10] Regional economists and geographers have made the distinction for some time, and many consider urbanization to be the dominant process influencing spatial economic patterns (Harrison et al. 1996).

[11] This discussion follows the explanation in Arthur et al. (1987).

independent random variables have long-term averages that mirror their expected values, with probability one. Once we reach a large number of tosses, the average settles down, and persists, within a very narrow interval around 0.5 (see Figure 1).

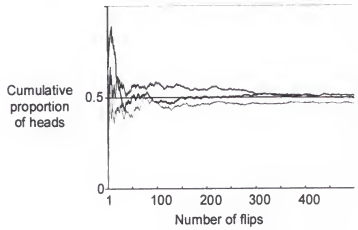

Figure 1. Law of large numbers with a fair coin.

Tossing a fair coin is a useful textbook abstraction. It is not a path-dependent process. In particular, there are no feedback mechanisms from consequences to driving forces. No matter what the *order* of coin flips, the same structure prevails in the end.

What about the example above, where locational choices can depend on other firms? *Path dependence* arises when probability p_j of an addition to region j depends on the existing geographic structure. Are there any strong laws to govern these situations? These kind of *economies of agglomeration* are quite widespread (Krugman 1991a), and are self-reinforcing. Is there a single likely equilibrium distribution, or are there multiple equilibria? What role do chance historical events play? To answer, we need to build some theoretical machinery. We need an alternative though experiment that has the same mythic quality as the ever-popular coin toss.

Assume an urn with infinite capacity. At the start, the urn contains one red and one green ball. Choose a ball at random; if it is red, replace it and add a red ball, and if it is green, replace it and add a green ball. On the next trial, and on all subsequent trials, the probability that a red ball will be drawn is precisely equal to the concentration of red balls in the urn.

Figure 2. Visualization of an urn process. In this case, there are 5 red balls and 4 green balls. The probability of drawing a red ball on the next trial is 5/9. $p_r=r/(r+g)$.

Notice that the probabilities are exactly equal to the proportions. This is a system which is self-reinforcing; where there is positive feedback. If a red ball is chosen, the probability that the next ball is red increases. It is found that the proportion of red tends to a limit X, with probability one (no drift). What is the limit X? *A priori* it is impossible to say, because X is a random variable. But the distribution of X is computable; X is distributed as a uniform random variable between 0 and 1 (see Figure 3).

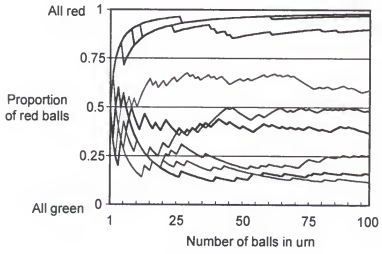

Figure 3. Ten runs (98 trials each) of a standard Polya process.

Just as in the fair coin toss, after early fluctuations, a structure emerges, but in this case the 'selected' structure is random. So in this model there are not just "multiple" equilibria, there are an infinite number. Arthur et al. (1987) show that in the more general case of starting from arbitrary number of red and green balls, the proportions still tend to a limit X, but X follows a two-parameter Beta distribution.

Causes and Results of Network Externalities

Arthur (1988) outlines four mechanisms that produce increasing returns, and thereby multiple equilibria and path dependence: large fixed costs, learning effects, coordination effects, and adaptive expectations. Network externalities fall under coordination effects, which Katz and Shapiro (1985) expand, noting three sources of positive consumption externalities. First, there are direct physical network effects (for fax machines, telephones, etc.—"Who am I going to talk to on this thing?"). Second, there are indirect effects—there will be more software for more popular computers, more games for more popular computer game platforms, etc. In regional economics, these are parallel to network spillover effects—technological innovation will tend to be shared among similar, nearby firms. Third, there are consumption externalities for durable goods, especially for service networks that support, say imported cars. In regional economics these are parallel to externalities caused by forward and backward sectoral linkages (Hirschman 1968). In a similar vein, development that favors automobile transport is autocatalytic, because of attendant pressures that call for road-building to support cars, versus other forms of investment. This is a common situation with boom/bust scenarios, because of the way government gets involved in facilitating a boom. Because of these externalities, the utility or profit derived from a decision depends on the number of other consumers in the network.[12]

Arthur has also noted four properties of self-reinforcing systems: multiple equilibria (or at least multiple domains of attraction), lock-in (or potential irreversibility), path dependence (the notion that history, or initial conditions, matter in the long run), and potential economic inefficiency (their most threatening property for economists). These are potentially attractive to resilience theorists, since they

partially describe dynamics that come from the adaptive cycle hypothesis.[13] The notions of lock-in and path dependence, in particular, seem to describe the evolution from box *r* to box *K* (see Figure 12 below), and potential economic efficiency is certainly one property that could engender crisis and reorganization. However, there are certain problems with the notion of path dependence as represented in the literature.

Limitations of Path Dependence Approach

In an article called "Sprayed to death: path dependence, lock-in, and pest control strategies" Robin Cowan and Philip Gunby (Cowan and Gunby 1996) point out several problems with the heuristic of path dependence, including (1) the difficulty of elaborating path dependency empirically when minor details can be the ones which set the pattern, and (2) the problem that comparisons have to be made with "what might have been." An incredible level of particular detail is required to demonstrate multiple states in a statistically rigorous manner, and prediction is necessarily ruled out (as evidenced by the literature on revolutions (Kuran 1989); thus evidence must be established from historical plausible alternative worlds. Nelson (1994) points out that it is difficult to distinguish between dominant design due to superiority or due to chance in the investment environment (the technology develops because it is receiving investment), because of the lack of counterfactual evidence. Even then, explanations can still be considered *ex post* rationalization.

Another limitation is that only basic adaptation is emphasized (see below, history or expectations). The fact that lock-in is implied does not change strategic behavior on the part of the agents involved—they cannot evolve either individually or institutionally, to cope with the impending inflexibility. A related issue is irreversibility: the path dependence examples are one-way games—agents play until they reach an

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[12] Note that the existence of potential equilibrium traps do not stop fax machines from invading the market, or compact disk from replacing LPs. The theoretical question for new technologies is the same as for exotic plant species: what are the conditions for successful invasion?

[13] The adaptive cycle hypothesis is discussed in the third chapter. In short, it postulates that systems will evolve from an exploitative and simple phase (called "Box 1" or *r* after a variable in the ecologist's logistic equation) to a tightly-organized and conservative phase (called "Box 2" or *K* after a variable which describes carrying capacity), with increasing specialization and efficiency. This phase may be disturbed by a crisis, either exogenous or engendered by the static and ossified *K* phase, at which point the system undergoes a phase of creative destruction or release ("Box 3") and reorganization ("Box 4"), before starting again on the Box 1 to Box 2 pathway. See Figure 12 and its accompanying text below.

equilibrium state—and no dynamics of escape are discussed. For example, most of the literature on regional economics focuses on issues of progressive lock-in, although some authors examine the effect of globalization as a wave of "creative destruction" (Florida 1996).

As noted below, the conditions that lead to path-dependence are not well-examined in a dynamic context (Kiser 1996); either they lead to path dependence or they don't, but the conditions do not change over time. What is often neglected are the ways that humans manage path-dependent situations, either to dampen its effects, or, more frequently to amplify it (as in booms and busts).

Other Examples of Path Dependence

Boom and Bust Literature

A general observation is that intervention or coordination is the frequent result when the dynamics of increasing returns (or other processes leading to multiple equilibria) are seen. There is a predisposition to coalition-building, both governmental and non-governmental, recognizing the power in being able to nudge the system. Politics and social forces therefore need to be taken into account in both the short and even in the long-run (Nelson 1994).

Related to path-dependence is the literature on boom and bust—a dynamic more frequently noted for its efficiency considerations than for its role in long term economic dynamics. The issue was recently raised at a workshop on economic development and land-use patterns in the Brazilian Amazon, a region noted for its extractive resource booms and subsequent busts (Pritchard et al. 1998). Oliver Coomes notes four major waves of economic activity in the Amazon, each of which has left a characteristic signature on the landscape (Barham and Coomes 1996, Coomes 1995). The question becomes, to what extent is development catalyzed by investment and extractive systems inherited from the past, rather than by current conditions and opportunities? How useful is history, and the historical spatial pattern of development, in predicting the future? To what extent is development in the midst of a boom *overdetermined*, and what is the legacy of a bust on future development?

Katz and Shapiro noted other positive externalities besides the ones listed above (Katz and Shapiro 1985): product information is more easily available for more popular brands (in a boom economy, this translates to more information available about the boom activity than for other potential activities). Also, market share is taken as an indicator of product quality (or as an indicator of profitability in a boom economy; it appears to be the sure thing)—this may be accompanied by a price bubble. Lastly, they note purely psychological, bandwagon effects. While other writers have noted particular properties of booms (Cohen and Levinthal 1994, Dixit 1992, Paich and Sterman 1993, Teece et al. 1994), they have failed to relate them systematically to their influence on long-term economic development.

Punctuated Equilibria

Several authors have extended the metaphor of punctuated equilibrium (Eldredge and Gould 1972) to social and economic phenomena. Since the review of Gersick's article (1991), which was discussed in Holling and Sanderson (1996), several other authors in the organizational transformation literature have been found to make use of the punctuated equilibrium heuristic for understanding technical and society change. These include Tushman and Romanelli (1985, Romanelli and Tushman 1994), who anticipated Gersick. This is a valuable heuristic to tap for research on path dependence and surprise, but one which is always in danger of being presented in too "neat and tidy" a fashion, drawing parallels, as it does, with more developed uses of the heuristic in other disciplines.

Human Response to Multiple Equilibria

As noted above, too often the issues of path dependence and multiple equilibria, if they are considered at all, are considered in a framework that may be evolutionary at the system level, but that does not influence the agents involved. This leads to an interesting set of questions.

When Do Multiple Equilibria Matter?

A key finding of the path dependence literature, and of the complexity and chaos literature on which it is based, is "sensitive dependence on initial conditions." The normative consequences of such dependence have motivated interest in this literature.

Krugman argues that "multiple equilibria are not a nuisance but a central part of the story" (1991a). This is an empirical question, but one that is driven by a set of conditions for understanding the stakes. When do multiple equilibria matter? Clearly, there exist meaningless or trivial equilibria (for example, unstable ones). Schelling's famous example is the seating arrangement in a lecture hall (Schelling 1978). There are a calculable number of multiple equilibria, but the advantages of one versus another are so indistinguishable that little effort will be expended to rearrange once attendees have chosen a seat. So the question is, when are there efficiency considerations at stake? If multiple equilibria exist but pose no potential welfare losses (either current or future, to ecosystems or to humans), then, however interesting, they may be unimportant.

However, even equilibria that are welfare-neutral are important when there are costs to lack of coordination (convention formation). A convention is a pattern of behavior that is "customary, expected, and self-enforcing" (Young 1996). In the face of multiple equilibria that are more or less equally desirable, conventions resolve problems of indeterminacy. How to choose a convention is another problem: They reduce transaction costs in some sense, yet choosing among alternative conventions is impossible in an ideally-rational game context (Schelling 1960:54-58). Sugden argues for several mechanisms, including history and expectations, to substitute for perfect rationality (Sugden 1989).

What Predominates, History or Expectations?

Gunderson et al. (1997) ask the question: when there are multiple equilibria in economic systems, which way does the Invisible Hand point? Given that multiple equilibria exist, and that they are meaningful and important, how is a particular equilibrium chosen? At this point most writers have highlighted the role of history (whether initial conditions, pre-determined variables in a Markov simulation, or ephemeral shocks) as a determining force. In most of the models of path-dependence,

current choices are governed by information about current conditions. In fact they are quite susceptible to shifts based on incorrect or limited information. However, if multiple equilibria matter, utility is at stake, and if humans understand this, one would expect that they would develop more robust, forward-looking strategies for behaving in such an environment.

Krugman begins to address this question in an article entitled "History versus Expectations" (Krugman 1991b), in which he argues that there are conditions under which expectations govern the choice of equilibrium, in the manner of "self-fulfilling prophecies."

For example, in Arthur's regional geographic model (Arthur 1987, 1995), locational choices are permanent. Since they are made based on current conditions, they are historically-dependent. Krugman asks why the choices are not made with regard to expectations of future earnings. If they were, it would create opportunity for self-fulfilling prophecies to occur (since if everyone believed the ultimate best location was in Region B, and knew that other believed it, they would settle there, regardless of current optimality). One could also argue that similar expectations keep startup firms out of software markets in which Microsoft would compete.

If expectations matter, there is an important role for human strategic intervention. Political campaigns, for example are largely fought over the expectations of success rather than over more substantive issues, since donors are likely to want to back a winner (many donors, however, hedge their bets by donating to opposing political parties—it is costly insurance in the event of an upset). Kuran has a model of surprise (unanticipated political revolution) that hinges on the threshold of expectation of successful overthrow (Kuran 1989). Note also, however, that focusing on expectations rather than history does not necessarily reduce the number of equilibria encountered.

If expectations are critically important to the structure of economic systems, and if, as in Arthur's example, expressing the choice is costly, there must exist ways to signal one's own expectations to ensure their consistency with others. There is certainly a role for "cheap talk" for signaling intent under such circumstances (Farrell and Rabin 1996). There would also exist rules for judging the credibility and compatibility of such expectations signals. Kuran argues that people make use of the heuristic of social proof, putting faith in the perception of society's collective judgment (Kuran 1993). In Arthur's model,

the rule is "show me"—participants judge intent by monitoring actions. It is often suggested in trade magazines that Microsoft exercises cheap talk by announcing shipping dates for software it is incapable of meeting, with the purpose of scaring off the competition (with so-called "vaporware").

Krugman develops a model of industrial location which incorporates both history and expectations, and their salience is weighted by adjustment costs (in his example, the cost of labor relocation). Adding the possibility of a role for expectations make a tremendous difference in the jointly-determined ecological/economic stability surface. Whether it simplifies or complicates the surface is indeterminate except in particular situations. Depending on the time horizon and discount rate of expectations, and the information used in forming them, the adaptive cycle dynamics are also relevant. Rather than considering different systems to exhibit different processes, as Krugman does, it may be possible to see the changing dominance of history and expectations both within and across cycles. Krugman has not reserved a role for learning in the formation of expectations, but clearly experience with several periods of crisis and growth would change the formation process.

The existence of a role for expectations in economic evolution does not diminish the concern about multiple equilibria. The caveat is, of course, not that humans need *a priori* knowledge about the possible multiple equilibria (because expectations would matter even if formed mistakenly), but that the *efficiency* of choices requires some knowledge about end-states. If equilibria are themselves evolving, there may be deep ignorance about welfare implications to choices along the way.

How to Control Path Dependence: Intervention or Coordination?

As Nelson argues (1994), if humans perceive that multiple equilibria exists and are path dependent—the long term structure is susceptible to perturbation—it is attractive to be the source of that perturbation. So humans will attempt to either intervene, or coordinate, in the case of network externalities. Such is the case with conventions—conventions may be arbitrary, but they must be stationary to be effective. If history has not provided a convention, then intervention may be necessary. Or, if history has locked in convention that is in some sense undesirable, intervention provides the signal to switch (as when the Swedes switched sides of the road to drive on).

In cases of multiple equilibria that exhibit path dependence, there is at least the potential to evolve an inefficient outcome. One way to determine the outcome is by fiat early in evolution. Early fiat may take the form of standard-setting, industrial policy, etc. The standard-setter would, of course need information on the welfare implications of various outcomes, which may be unavailable, or more likely non-existent, *a priori*. (In fact, industrial policy is not at all guaranteed to generate outcomes more desirable than autocatalytic evolution). Fiat need not be top-down—a cartel of producers may also set an industry standard, either in the interest of productivity, or to gain market share against rival technologies. Anti-trust legislation attempts to avoid the dynamics of lock-in, but deals poorly at capturing the efficiency results of preventing economies of scale.

Adapting to Equilibrium

One alternative is to adapt to the equilibrium within which one find oneself. Arthur discusses this in terms of investment in R&D for a emerging technology (the "winning" technology receives the lion's share of attention, thus further ensuring its success). The "paradox of ecosystem management" (Holling and Meffe 1996) is that such an adaptation may contain the seeds of destabilization. A winning management system reinforces itself, because the best information is about the existing scheme. Kuran (1991a) discusses a situation in which a fulfilled expectations equilibrium in a democracy leads to evolution in private preferences, because people are pleased with the equilibrium. But because they begin to adapt their private preferences to the equilibrium, the equilibrium point moves, and the system is destabilized.

Escape from Lock-in

Liebowitz and Margolis's conclusions about escape from lock-in manifest their faith in spontaneous organization for optimality: "Where there is a knowable and feasible improvement to be gained from moving onto a better path, those who will benefit from the improvement, and who know it, will be willing to pay to bring the improvement about. Where simple spot-market transactions are insufficient to bring

these improvements about, institutional or strategic innovation seems a likely response, especially if the improvement is important enough that the innovator is likely to be well paid.

In general, however, once a system has reach one of several multiple equilibria, moving to a different, possibly more efficient equilibria will entail at least transitory welfare loss. Whether all agents can tolerate that welfare loss, given their discount rates, is an open question—but evidence from technology choice in typewriter keyboards and videocassette recording indicates that the answer may be negative. Hence, a move may not be Pareto-safe.

The options for overcoming lock-in, and moving between equilibria, include revolution, late fiat (which requires a great deal of power), or expensive coordination. Theories of annealing suggest that "shaking the system" is enough to move the system into an alternate (and potentially more desirable) stability domain, but with the systems we have been describing the depth of the adaptive surface itself is changing as a result of endogenous processes. There annealing solutions may be of dubious significance. The alternative is wait for the hurricane, or economic downturn (or economic upturn). What is the result of smoothing out all the things that could reset the clock? Are there any guidelines for predicting successful invasion in the absence of such disturbance?

For problems of distributional lock-in (and almost by definition, any Pareto-efficient distribution is an equilibrium), one of the only escapes is growth in the grand utility frontier. Otherwise, altering the equilibrium outcome will involve redistribution (Pareto-unsafe moves), about which the standard economic paradigm has little to say. Knight argues that almost all institutional innovations are Pareto-unsafe, which is why he argues for the importance of understanding power and distributional issues (Knight 1992).

Bounded Rationality

While recent advances in cognitive science have again highlighted the importance of bounded rationality in the development of human institutions, that literature has been recently reviewed elsewhere (Conlisk 1996). North has recommended this literature to economists for the new frontiers it opens up for understanding institutions and bounded rationality (North 1993).The distinctiveness of the bounded

rationality literature is its focus on imperfect rationality rather than imperfect information, because of the need to "economize on economizing" (Day and Pingle 1991)—the deliberation cost problem, as distinct from the transaction cost or the information cost problems. Bounded rationality is appealing in that it adheres to an economic notion for its explanation of institutional behavior—that human cognition is scarce and therefore costly. The prior decision is to choose a decision-making method, which will not necessarily be strict optimization, since that can be complicated (ask any engineer).[14] Further appeal comes from its empirical and mechanistic bent—adding nuts and bolts to the "gee-whiz" results of many other path dependence/multiple equilibria models, allowing predictions to be made about when systems would be expected to show the above-mentioned dynamics, and when not. I focus on several representative notions of bounded rationality which hold particular promise for enlightening ecological economic research.

[14] There is the chance that deciding how to decide will necessitate a prior decision about how to decide that—an infinite regress issue discussed by Lipman (1991).

Two of the innovations in thinking about social interactions and uncertainty deserve further attention, because they go to the heart of at least two of the prescriptions which have gained popularity in the environmental management community. One of the prescriptions is a comprehensive flexibility at all hierarchical levels, and the other is for increased reliance on cooperation, consensus, and community.

Flexibility and Rigidity

> "Ecosystems are moving targets, with multiple futures that are uncertain and unpredictable. *Therefore human management has to be flexible, adaptive, and experimental at scales compatible with the scales of critical ecosystem functions*" (Holling and Sanderson 1996, my italics).

One of the most often repeated prescriptions for enlightened ecological management is that all actors at all scales—resource users, user groups, management agencies, regulatory agencies, academics, policy-makers—should be flexible, adaptive, and experimental: in short, they should practice adaptive management. Inflexibility, rigidity, obstinacy and intransigence are the enemies of best ecosystem management. Yet under certain circumstances, it may be argued that rigidity is understandable, even...adaptive. Reliability theory offers one set of explanations for relatively inflexible behavior.

Reliability Theory

Ronald Heiner (1983) argues that the origin of predictable behavior is not in situations where human agents model their environment well, but in those situations where there is a high level of uncertainty. In highly certain environments and with perfect rationality, human behavior could exhibit an "adaptive radiation," blossoming in complexity and subtlety to ensure optimal choice in every possible situation. Instead, in observing many forms of human behavior, we see remarkable predictability, consistency, and rule-following. Why?

Heiner hypothesizes that humans add behaviors to their repertoire under the condition that they can choose when to use them reliably. Unreliability comes from (a) environmental complexity and (b) human fallibility, in perception and in decision-making. There is a gap between the *competence* of the agent and the *difficulty* of the environment. Heiner develops a "reliability condition" which says that the gains from choosing the right behavior at the right time must be greater than the potential losses from choosing it at the wrong time. Only if the reliability condition is met is a behavior added to the repertoire. If this is true then flexibility is not necessarily a good thing. Flexibility only improves performance if the reliability condition is met.

To provide some formality to the approach, consider the following[15]: let the set of possible actions be D, with individual decisions described by $d \in D$. If information i_d is received, the action d is optimal. Assume that information i_d is received with probability p_d. Let the conditional probability of an agent picking action d when information i_d is received be r_d (because action d is the right decision). At any other time (when information is not i_d), let the probability of picking decision d be w_d (i.e., action d is the wrong decision). If $r_d = 1$ then the agent always picks decision d when it is appropriate to, and if $w_d = 0$ then the agent never picks decision d when it is not appropriate. Such an agent makes perfect decisions—without mistakes. If an agent sometimes fails to pick decision d when it is appropriate, then $r_d < 1$ (a Type I error in statistical terms). If the agent sometimes picks decision d at an inappropriate time, the $w_d > 0$ (a Type II error). The ratio $\rho_d = r_d / w_d$ is the agent's *reliability* for action d. For perfectly reliable agents, $\rho_d = \infty$. For the rest of us, ρ_d is usually finite.

It is reasonable that there is a payoff (gain) for making the right decision at the right time (call it g_d). Likewise, there is probably a cost (loss) associated with making the same decision at the wrong time (call it l_d). If the opportunity to make the right decision comes around with probability p_d, then my expected payoff will be $p_d\ r_d g_d$ (the probability of opportunity, times the probability the agent chooses well, times the gain from being right). The cost of making the decision d at the wrong time is then $(1 - p_d)\ w_d\ l_d$ (the probability that the agent has the opportunity to be wrong, times the probability that he is wrong when he has the chance, times the loss from being wrong).

Clearly, an agent would only want to have the action d in his repertoire if the expected gains exceed the expected losses, or

$$p_d \, r_d \, g_d > (1 - p_d) \, w_d l_d .$$

Solving for reliability (which depends on the agent) on the left hand side yields a right hand form which depends on the environment, giving a threshold for including the action d in the repertoire of behavior:

$$\rho_d \equiv \frac{r_d}{w_d} > \frac{l_d}{g_d} \cdot \frac{1 - p_d}{p_d} \equiv T_d .$$

An agent would only want to consider having the action d in his repertoire if he could perform it with sufficient reliability, that is if $\rho_d > T_d$.

One possible hypothesis resulting from this postulate is that with increasing reliability, behavioral options will be added "in order." That is, with decreasing environmental complexity, or increasing perceptual ability, all the preceding behaviors will be retained, and the order in which others are added will be deterministic.

Heiner thus proposes a way to answer the following kinds of questions:

- When will a person (or group) decide to be behaviorally responsive to particular information, and when will they be unresponsive?
- When is the right time to search for more information?
- When is it the right time to learn?

A clear extension results: when humans are interacting with other humans in a social environment, there is considerable uncertainty—thus social institutions evolve to structure behavior. Note that Heiner's argument is not that they evolve *to reduce uncertainty* (although that is a second order effect), but rather evolve *in response to uncertainty*, because humans are unable to respond optimally to numerous and hopelessly complex sets of relationships. Institutions result not from sophisticated understanding of the environment, but from the inability to cope with its complexity. To quote Heiner (1983:580):

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15 Nomenclature modified from Milon and Boggess (1988).

> In general, further evolution toward social interdependence will require institutions that permit agents to know about successively smaller fractions of the larger social environment. That is, institutions must evolve which enable each agent in the society to know less and less about the behavior of other agents and about the complex interdependencies generated by their interaction (Heiner's italics).

The market would appear to be one such institution.

Heiner refers explicitly to the punctuated equilibrium literature, and especially to Kuhn (1962), in pointing out that lack of reliability will cause scientists (or bureaucrats) to resist new theories and to systematically ignore accumulating evidence. A further elaboration would be useful in explaining why certain sets of scientists recognize anomalies and accept alternative theories. Heiner also offers an example of systematic hysteresis in switching between allowing and disallowing an action, through recursive application of the reliability condition, which is an alternative to the risk-based hysteresis predicted from investment theory (Dixit 1992). The more general point, though, is that economic behavior may be far more governed by switching and hysteresis than traditional optimization theory indicates (Heiner 1983:582).

The implication of Heiner's work is that when the environment is complicated, simple rules will be followed, and that in simple environments, more elaborate alternatives may be considered. Then, in one sense, the complex and loosely structured environment of the release and reorganization phase begs for the simple rules-of-thumb, slogans, or rallying cries that govern the initial stages of exploitation (the *r*-phase). The *r*-*K* evolutionary path (see Figure 12) could be understood as a narrowing of the competence-difficulty gap. Adaptation, learning, and adjustment all increase the competence of agents in the face of an increasingly well-known environment—an environment that they increasingly control for a narrow range of outputs. Greater knowledge may increase their flexibility in adjusting to the slightest perturbations, allowing them to track their desired equilibrium state with great accuracy. If the process of *r* to *K* consolidation decreases the C-D gap, it also leads *in itself* to vulnerability to alternate rules, development programs, etc. but chiefly as refinements to an existing repertoire of behavior.

What Heiner doesn't consider is a feedback effect from behavior to the environment. A repeated observation from ecological cases is that management systems that are successful at "doing what they do" (which in the case of resource management is usually maximizing and sometimes stabilizing a set of

outputs) tend to change the underlying system in ways that lead to crisis. Adding to and refining a "management system" by increasing competence, in this line of thought, has a feedback effect on the difficulty of the environment which may be manifested in a change of probabilities or a change of payoffs.

Another, perhaps more plausible, way to consider system evolution during the r to K trajectory is to think of successful management as decreasing the probability of rare events (putting out forest fires early, spraying for pest outbreaks, instituting flood control practices). By manipulating the environment to reduce the frequency of rare events, they raise the threshold of reliability for the actions that are appropriate in those events. Actors, it is predicted, will "forget" those actions where the threshold exceeds the reliability of application. By rarely experiencing crisis events, actors will lose their ability to reliably estimate the probability of their occurrence.[16] The repertoire of "active" behaviors will shrink, and management organizations will be able to invest considerable resources in doing a few things well.—that is, they will invest in increasing their reliability for the remaining actions, and may also experience greater gain for appropriate application of those actions. By not experiencing periodic crises, management will become rigid and narrowly focused. This is indeed the argument made by Folke et al. (1998) about modern management systems compared with traditional ecological management systems.

As Heiner describes reliability theory, it applies chiefly to individuals; he does not create a strong theoretical link for using reliability theory to describe social process (Kuran 1988). Economists tend to find it surprising when organizations spontaneously choose command-and-control over market incentives for a wide range of environmental management objectives.[17] Reliability theory may help to explain the seeming bias. The precautionary principle may be one example of selection for reliability rather than efficiency (see below).

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[16] In a similar context, Stephen Carpenter has noted that successful management will minimize opportunities for learning about the environment, by managing for a stable system (personal communication).

[17] At a meeting of economists a discussion was underway about the "silly system of rules" that one economist's neighborhood had imposed on the use of noisy leaf blowers; the choice was particularly egregious because the neighbor's had explicitly rejected the economist's proposed system of efficient economic disincentives. When I asked why the neighbors might have revealed a preference for rule-governed behavior, the best answer I received was that "we simply haven't done a good enough job educating the public in economics."

Collective Conservatism

Conservatism is of various types. Heiner elaborated a mechanism behind individual conservatism. This section examines the mechanisms behind an important theory of collective conservatism. Timur Kuran (1989, 1990) relaxes the assumptions of individuality, and of the sovereignty of the consumer.

Dual Preferences

Kuran suggests that a wide range of political and economic phenomena, including revolutions (political and scientific in Kuran 1995; surprising and sudden changes in public opinion in Kuran 1987a; and preservation of the status quo in the face of seemingly significant changes in driving forces in Kuran 1987b), can be explained by recourse to a dual preference model. In Kuran's model, agents have a *private preference* for a policy choice (for simplicity, consider the policy choice to be binary—support the status quo or oppose it) known only to themselves. They also have a *public preference*, but there is no overriding reason why they should be honest about expressing their private preference. For a whole range of reasons, they may choose to publicly falsify their private preference—perhaps to avoid hurt feelings, alienation, or violent reprisals. This is not to say that public and private preferences are unrelated; there is at least a psychic cost to dishonesty, but this must be weighed against the costs of being honest.

Kuran distinguishes three forms of utility that together determine an agent's publicly announced preference (Kuran 1995b). *Intrinsic utility* is the most fundamental, and is what most economists mean by utility. *Expressive utility* is the utility that comes from being honest—it can be thought of as the utility that comes from reducing cognitive dissonance. In general an individual will get the highest utility from saying what they really think. The third form is *reputational utility*, the utility that comes from what others think about my public preference. In a pro-business environment, a contractor who expresses concern for wetlands protection may be sacrificing reputational utility because she values being honest more. In an anti-business climate, we might suspect that an environmentalist contractor is falsifying their preferences to gain reputational utility.

Reputational utility becomes an important factor in certain circumstances. Two applications of the idea are not so salient for environmental management, although they may contribute. One is the most

pervasive form of preference falsification that contributes to general politeness.[18] Kuran's original application is the second—analyzing the cost of expressing opinions in highly repressive and often violent religious fundamentalist regimes.[19] The effect of reputational utility may be subtle but important in other contexts, for example where an agent is unsure about the validity of his private beliefs, where the consequences of dissent are unknown, or where there is pressure to generate a consensus opinion. The dual preference model is applicable to discourse in democratic societies, or in public and private organizations such as firms, churches, and bureaucracies (Kuran 1991a). Some of these contexts are discussed below.

Thresholds

The implication of a possible difference between private preferences and their public expression in a wide variety of circumstances is that reputational utility will be dependent on prevailing *public opinion.* If an agent has an intrinsic utility which would make him tend to oppose the status quo, but he knows that most people support the status quo, concern for his reputational utility might temper his public opposition. In general, we would hypothesize that reputational utility would be a function of the numbers of people supporting or opposing a position publicly, which Kuran calls *public opinion.* If reputational utility matters enough to an agent who privately supports the status quo, there will be some threshold of public opinion against the status quo that will cause him to hide his support (or to falsify his preference by denouncing the status quo). Holding intrinsic and expressive utility constant, we could describe a population of agents by their thresholds for opposing (or supporting) a policy. Agents whose intrinsic utility gives them a private preference against the status quo may not require that there be very many fellow dissenters before they publicly express their disapproval. Private supporters of the status quo will maintain their public support for much longer—they may require evidence that a substantial majority opposes the status quo before they join them. Supporters who do not care about reputational utility will

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[18] For example, there is no reason for me to publicly denounce your choice of necktie or scarf just because I do not personally care for it—although I may do so anyway.

[19] This is not to say that there are not situations where the threat of violence is an important factor in environmental controversies.

never falsify their preferences—their threshold would be over one-hundred percent opposition. Opponents who don't care about reputational utility will declare their opposition even if no one else does. Their threshold is zero percent opposition.

Suppose there is a population of ten individuals with the following thresholds (Frank 1996):

Agent	A	B	C	D	E	F	G	H	I	J
Threshold	0	20	20	30	40	50	60	70	80	90

Agent A will express opposition to the status quo even if no one else does (perhaps the opposing policy gives her very high intrinsic utility, or perhaps she does not care about reputational utility). Agent J will only publicly oppose the regime if 90 percent of others do. This population has two stable equilibria. If only Agent A speaks out against the regime, there will be a 10 percent opposition. It would take a public opposition level of 20 percent to convince anyone else to publicly oppose the regime. At equilibrium, the status quo has an overwhelming majority of public support: 90 percent are favorable. The other equilibrium is a corner equilibrium at 100 percent. If everyone believed that everyone would oppose the regime, they would all oppose it.

What can disturb the lower equilibrium? How could a revolution start? First, suppose that Agent B's threshold changes. Maybe he reads a stirring pamphlet by Agent A, or sees a family member hurt by the status quo policy. Suppose Agent B's threshold drops to 10. Then Agent B sees Agent A's public opposition, and concludes from her that at least 10 percent oppose the status quo. He declares his opposition, making a 20 percent block of dissent. Agent C sees this and joins in. A bandwagon effect ensues, and the regime falls in short order.

The effect of representational utility makes this model one of increasing returns, both to opposition and to support for the status quo. Very small factors, such as Agent B's change of heart, can have dramatic effects on the equilibrium. History plays an important role in determining which equilibrium prevails, but here history works *through* expectations. If public dissent is virtually non-existent (except for the voice of Agent A crying in the wilderness), no one would have any reason to expect anything different. If it is clear that everyone opposes the status quo, then that expectation would maintain the upper equilibrium.

The equilibrium could also be disturbed if it were possible to manipulate the *perception* of public opinion. If an activist could convince either Agent B or C in the original population that 20 percent of their fellow citizens opposed the status quo (and it didn't contradict their own estimate of public opinion), then they would join the opposition and start the bandwagon rolling. This suggests to Kuran that if reputational utility is seemingly important, then activists will do what they can to appear that they command the support of a silent majority (Kuran 1991a).

Another way to view the stability of regimes where preference falsification is a factor is by using propagation curves to show the mapping between expected public opposition and actual public opposition. Figure 4 shows one such mapping, for a population with a threshold distribution that shows three equilibria (two stable and one unstable). Equilibria occur where actual public opposition matches expected public opposition. The unstable equilibrium forms a separatrix between the domains of attraction for the other two. The graph shown in Figure 4 has two equilibria, and which equilibrium prevails is determined by expectations. If those expectations are governed by history, as would frequently be the case, then the graph represents a model of collective conservatism.[20]

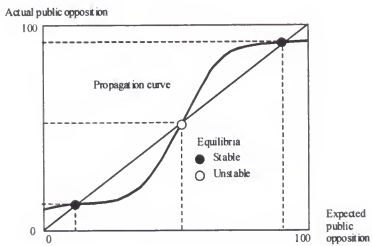

Figure 4: Propagation curve with social interaction

[20] Below, Kuran's characterization of the role of history versus the role of structure is discussed.

Other contexts

If Kuran's dual preference model were only applicable to situations of surprising political revolution under regimes of power and oppression, it would be a useful example of a social model of multiple equilibria, path dependence, and historicity. It is more widely applicable, however. For example, it can be a useful description of the dynamics of belief systems, including beliefs about alternate scientific hypotheses, when those beliefs are held to varying degrees.

In many circumstances there is pressure to express support for alternate hypotheses or theories, even if the support is not well grounded. Survey research, for example, shows that respondents are frequently willing to express opinions on issues about which they know little, even to the point of expressing strong opinions on completely fictitious issues (Bishop 1989). Framing effects are well known in survey research (Tversky and Kahneman 1981, Bowles 1998), and are important in contingent valuation research (Carson 1991, U.S. Department of Commerce/National Oceanic and Atmospheric Administration 1993). Inasmuch as the dual preference model has implications for the reporting of private preferences, it is useful to explore even in contexts where framing or questioner bias is slight.

If there is temptation to preference falsification even in non-threatening survey research, then the application to open public discourse is even more evident. In assessing complicated and subtle issues, many of us rely not just on our own (often quite limited) judgment, but on the opinions of others around us. In other words, some of our knowledge is based on our own personal experience, or on the proof of scientific experiments we have conducted. The rest of our knowledge is based on what others have told us. In Kuran's words, some of our knowledge is "hard" and some is "soft." Our soft knowledge may in fact be true, but not because we ourselves have proved it. Kuran's theory applies to these circumstances as well—it becomes not so much a dual preference model as a dual knowledge or dual belief model.

A simple version of such a model would run as follows: If I have incontrovertible proof of a hypothesis (a simple notion for a simple model), then I do not need to rely on the opinions of others. Even if scientific opinion discounted my hypothesis completely, I would stand by it (my threshold would be 100). My scientific opponent believes he has evidence which refutes my hypothesis, and he is willing to stick with his proven refutation even if everyone (mistakenly, in his view) decides to support me. He has a threshold

of 0). Other scientists (and certainly the general public) may be in the middle, unsure which side to believe with certainty. If they are concerned at all with their reputations, they *may* tend to pick the side which has the most supporters. This method of establishing belief has been called "social proof," and is one of the chief reasons why repetition is such a successful advertising device (Moorthy and Hawkins 1998, Cialdini 1984). Kuranian dynamics apply.

A more subtle version of the model would allow agents to express indecision rather than forcing them to choose side, and would distinguish which group they look toward for their reputational utility. In other words, agents may look to similar agents to find out what they ought to "reasonably believe" about an issue. Democrats may look to Democrats, evangelical Christians may side with other believers, and neoclassical economists may put their trust in disciplinary orthodoxy. Certainly underlings in a scientific or regulatory bureaucracy, grad students in a laboratory, and tenant farmers on a large property may find it reasonable to adhere, with more or less reservation, to their superiors' more knowledgeable opinions. None of these examples should be thought to cast doubt on the sincerity of belief—they are merely to note that beliefs, even when true, need not be grounded in fact or experience. They can be soft.

The implication of a dual knowledge model is that while hard knowledge is acquired at cost and is durable, soft knowledge is relatively cheap, and is much more malleable. When circumstances change, soft knowledge is readily adapted to a new situation, while hard knowledge may not pass away until its owners do. If all knowledge is hard, no one needs anyone to tell them what to believe, and the propagation curve is a horizontal line that marks the divide between believer in alternate hypotheses. Expectations about public opinion have no effect on the equilibrium public opinion—it simply measures the certain advocates on both sides of the issue. If all knowledge is soft, then actual public opinion is much more dependent on expected public opinion. If both kinds of knowledge are at work in a controversy, then actual public opinion will be dependent on expected public opinion in a limited range (Figure 5).

Feedbacks effects

Kuran does not deal only with how private preferences interact with public opinion to reinforce or subvert that public opinion. Kuran discusses two kinds of feedback effects from public discourse to private beliefs, which occur on two scales, intra- and inter-generational.

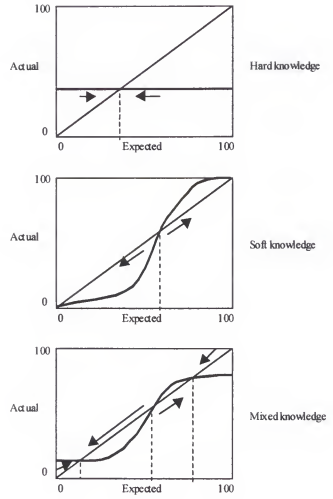

Figure 5. Propagation curves for hard, soft, and mixed knowledge systems

Because people are bounded in the cognitive capacity, they rely to a greater or lesser extent on public opinion, social networks, and other mechanisms to justify their opinions (Kuran offers a number of reasons why this is economical, in the spirit of deliberation and information costs).

Why do heterodox views persist or degrade in the face of public pressure? Festinger's view, based on the notion of cognitive dissonance (Festinger 1957), is that it is easiest to accommodate preference falsification, and to maintain private preferences at variance with society, when the social pressures are the greatest ("I admittedly did such-and-such, but only to save my life."). In contrast, since it is harder to justify preference falsification when the social pressures are light, the discomfort of cognitive dissonance

will lead people to modify their private preferences. However, the harshness of social pressure is not independent of the depth of private convictions. Kuran's explanation of the same phenomenon is that harsh threats are made to overcome deeply-held convictions based on personal rather than social proof, and thus the effect of mental inertia will be greater, allowing the private-public disharmony to persist. Where social pressures are substantial but not overly harsh, it is because views are considered more malleable, as indeed they prove to be.

Because of the complexity of preference evolution, and the interaction between the scales of public and private, Kuran is able to develop a model of sudden change in preference expression that is similar to the dynamics of the adaptive cycle, in that equilibria are fundamentally unstable over the medium-to-long term. He posits a distribution of privately-held beliefs which evolves in response to the success of public policies.

Kuran further develops an intergenerational theory about the transmission of preferences.[21] While within a single generation, private preferences are either expressed, suppressed, or transformed in their public revelation, it is the public discourse which most affects the next generation's private preferences. His argument is not deterministic—that what is unthinkable in one generation becomes the unthought in subsequent generations—only that is becomes *less likely* to be thought, and thereby he elaborates a reasonable mechanism for social forgetting. Rediscovery is theoretically possible, particularly for information that depends on personal experience rather than social proof, but it need not occur with probability one.[22]

If private subversive preferences are not transmitted, then the social status quo will be more likely to persist, and to be tacitly transmitted. Kuran points out that tacit transmission of knowledge is important with or without preference falsification on the part of the elders (even sincerely expressed ideas can be accepted without question), but that the boundaries of tacit information are affected when certain

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[21] The argument relates well to the dual-inheritance model posited by Boyd and Richerson 1980, 1993), in which genetic and cultural evolution take place simultaneously.

[22] The extension to organizational forgetting is obvious, and one would expect it to be more accurate with higher employee turnover. See *The Economist*, "Fire and Forget," April 20, 1996, p. 51-52 for the costs of "corporate amnesia" as a result of downsizing.

information is not transmitted. In Kuran's words, "society exerts more influence on *what the young think about* than on *what they think*" (Kuran 1993:497, author's italics).

Spatial variability, social networks

What Kuran's exposition lacks is an explicit treatment of stratification or sorting of society into clusters of like-minded individuals reinforcing heterodox beliefs (intellectual refugia). Schelling's tipping model is the archetypical example (Schelling 1978). In such a model even minor signals about differences may lead to comprehensive segregation. Kuran's is a structureless , well-mixed society in which public discourse takes place at a macro-level; it does not leave room for such sub-groups, and so his model of preference evolution reflects the dynamics of competitive exclusion (Odum 1983). Introducing heterogeneity in the environment may complexify the results.

Spatial Version of Kuran model

It is highly unlikely, even in an age such as ours with the omnipresent public opinion poll, that people rely on the public opinion of the entire population for social proof. A more accurate statement would be that public opinion is discounted over social distance. An agent will typically care more about his reputation with his nearest neighbors than with those who are socially distant. Kuran's models are typically for "infinite" groups, where the effect of public opinion on reputational utility is undiscounted. Because there is no concept of social distance in the model, small changes in public opinion have the same effect on perceptions of public opinion, and on each agent's preference revelation, no matter where they occur in the society. What implications would social distance discounting have on Kuran's model of dual preferences?

A relevant model of dual preference (or dual beliefs or social proof) could be constructed in a number of ways. One way is to consider social distance to be related to physical distance, and to construct a "spatial" model of interacting agents on a "landscape." If there is discounting, then closer neighbors will have a greater effect on the public expression of private opinion than more distant members of the population.

Kuran's models of preference falsification jump back and forth between concrete examples using a population of ten individuals to statistical examples with general populations of an infinite number of interacting individuals. Most of his arguments assume that all the individuals in a population interact—that when an agent perceives *public* opinion, the relevant public is the entire population. In many circumstances we would hypothesize that individuals interact with subsets of the entire population—what we will call *neighborhoods*.

To investigate the effect of limited neighborhood interaction on Kuran's model, a numerical simulation was performed using *Mathematica*.[23] A population of 121 individuals (which we will call our *society*) is positioned on a square lattice. Each agent is immediately surrounded by eight other agents. The lattice has *periodic boundary conditions*, meaning that it is "virtually" wrapped in such a way that agents on the southernmost edge have southern neighbors on the northernmost edge, and vice versa (the same applies to the western and eastern edges).

Agents are assigned a threshold, a level of public opinion in favor of the opposition that will persuade them to publicly express a willingness to support the opposition. Agents are allowed to interact only with other agents in their neighborhood to form their estimate of public opinion. Once they estimate public opinion they decide whether or not to publicly express support for the opposition or for the status quo. Every agent publicly supports one or the other position. In this model, the underlying private variables determining the threshold are not important; the distribution of thresholds in the population determines the behavior.

Agents are drawn from a population with a given threshold distribution function and are placed randomly on the lattice. A prevailing level of public opinion is "announced" to get the simulation started. Agents then express their public preference based on the announced public opinion, and then estimate public opinion for themselves based on the publicly expressed positions in their neighborhoods. A period of adjustment occurs, but the process soon results in an equilibrium (the speed of adjustment depends on the size of neighborhoods).

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[23] The *Mathematica* code for this model may be found in an appendix to this document.

Neighborhoods of varying shapes are used in the literature; for this model, variants on the *Moore neighborhood* are used (Gaylord and Nishidate 1996). Typically the Moore neighborhood consists of nine sites: a given site and its nearest neighbors to the north, east, south, west, northeast, southeast, southwest, and northwest (Figure 6). Since this neighborhood consists of a site and all its neighbors one cell away, this neighborhood is called the Moore[1] neighborhood. For investigating the effect of neighborhood size on Kuran's dynamics, other Moore-type neighborhoods can be created. The Moore[2] neighborhood comprises the site and all the neighbors within two cells, adjacent and diagonal, for a neighborhood size of twenty-five sites. The general relationship between Moore number, m, and neighborhood size is $N = (2m + 1)^2$.

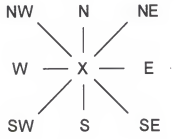

Figure 6. The Moore[1] neighborhood

For this example, a threshold distribution function with the propagation curve in Figure 7 was used.[24] This threshold distribution function has stable equilibria at 9 percent and at 91 percent, and a single unstable equilibrium at 20 percent.[25] As we shall see, the propagation curve is really defined only for a thoroughly mixed population, where estimated public opinion is based on the entire population and not on neighborhoods.

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[24] The exact threshold distribution is eleven individuals have a threshold of zero (meaning that even when the expected public opinion in favor of opposition is zero, they still express opposition), thirty-three individuals with thresholds of twenty percent, and the remaining individuals (seventy-seven) have thresholds of thirty, forty, fifty, sixty, seventy, eighty and one-hundred percent (eleven individuals with each threshold).

[25] Actually, in this model there are a discrete number of individuals (121), so that there can never be exactly twenty percent of the population holding an opinion. Technically, therefore, 20 percent is not even an unstable equilibrium, but it is the separatrix between the other two equilibria. If more than 20 percent

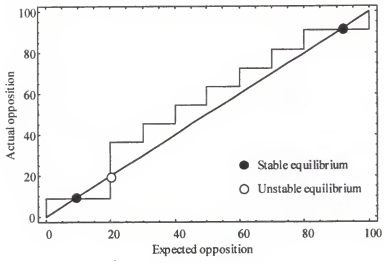

Figure 7. Propagation curve for simulation example

Varying the neighborhood size has tremendous consequences for the realized level of public opposition. The program was run 2000 times, with an initial announcement of 5 percent support for the opposition, for each of five Moore neighborhood sizes, and the resulting level of public opposition was measured (Figure 8)[26]. With a Moore number of five, the neighborhood size was 121—the whole population. As is expected from the propagation curve in Figure 7, public opposition moves to about 9 percent for all 2000 trials. The random spatial pattern of the population makes no difference whatsoever when everyone knows, not what everyone else is thinking, but what everyone else is saying. Contrast that with the results from 2000 random trials (each trial places the individuals randomly on the landscape) when the neighborhood has Moore number of 1—a neighborhood size of 9. A whole range of results are possible with such a small neighborhood size—publicly announced levels of opposition range from 11 to 80 individuals, depending on the random spatial arrangement. Because each agent samples only a small proportion of the population, the agent's estimate of public opinion will vary considerably.

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of the people are expected to support the opposition, a chain reaction of declared opposition will raise the actual opposition to 91 percent.

[26] That is, 2000 random configurations were generated using 121 individuals with the given thresholds. Each of these configurations was used five time, once for each neighborhood size.

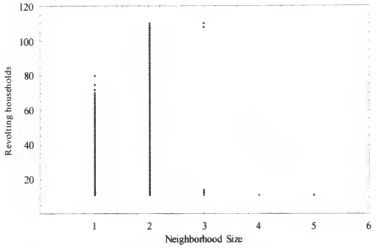

Figure 8. Results of simulation with varying neighborhood sizes from 9 to 121 (the whole population), with an announced initial opposition of five percent, and with the threshold distribution from Figure 7.

Not only will agents "misjudge" the level of public opinion, depending on who happens to be in their neighborhood, they will pass on their misjudgements by making a public declaration of support for the opposition or the status quo. That is, an agent's assessment of public opinion is based on the declarations of those around him; he used those declarations, along with his private threshold, to make his own declaration, *which then alters the estimate of other agents in his neighborhood.* This contagion effect is seen in Figure 8 (and in Figure 9, which repeats the same data), by looking at the Moore[2] neighborhood. In this set of 2000 runs, 2 modes emerge. In most of the runs, the neighborhood is large enough that agents get a pretty close estimate of the population level of opposition; as a result, the announced opposition tends to hover around the lower equilibrium (11 publicly discontented individuals, about 9 percent of the population). By sampling a larger area, individuals are able to get a lower variability estimate of public opinion, and their responses, even with a neighborhood of 25, are close to the responses that are achieved with a neighborhood of 121.

In situations where, because of the random placement of agents on the lattice, there is a higher *perception* of public opposition, that opposition tends to propagate itself, because of the substantial overlap between neighborhoods. Now, an agent's perception of public opinion is influenced not only by the perceptions of his nearest neighbors, but by those of their neighbors as well. If my neighbors think

rebellion is likely enough to express public opposition, *their* neighbors, sharing most of the same information sets, will also think it likely enough. A neighborhood size of twenty-five is sufficiently large to see this phenomenon, but still small enough to have the necessary variability to start a rebellion in the first place.

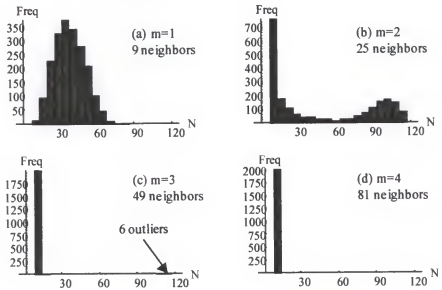

Figure 9. Histograms for each of four Moore neighborhoods from the previous simulation. N is the number of agents revolting, Freq is the frequency

Figure 9c shows the results with a Moore[3] neighborhood (size=49). In this case, the fact that each agent samples approximately half the population means that their estimates of public opinion are almost always very accurate. Six of the two thousand random configurations permitted a rebellion to start, and the very substantial overlap in information between individuals meant that the spark was sufficient to start a blaze. The large sample size meant that the spark of variability was noticeably absent. The high degree of connectivity (shared information) means a high degree of contagion, but the large sample sizes mean that an "epidemic" is almost impossible to start. A Moore[4] neighborhood (81 neighbors) is so large that no mistakes are made in estimating public opinion—public opinion moves to 11 individuals (9 percent) and stays there for every one of the two thousand random configurations. The results are the same for the Moore[5] neighborhood (121 nieghbors, shown in Figure 8 but not in Figure 9).

The overlapping neighborhoods is important to this model; each agent has his *own* neighborhood. A model that simply partitions the population into fixed neighborhoods would be more likely to find rebellious enclaves than a thoroughly mixed population, but the rebellion would be a contained rather than contagious phenomenon.

Spatial Model Discussion

The spatial model of dual preferences gives us several lessons. One is that when social interactions are discounted over distance, then consensus-building becomes a path dependent process: spatial configuration matters (or more accurately, social networks matter). When neighborhoods are small, information discounting across distance is high, and the same individuals, with the same private preferences and thresholds, will sometimes support the status quo, will sometimes support the alternative, and, as seen in Figure 8, can also find themselves supporting almost any position in between. Not only does spatial configuration matter, but neighborhood size matters as well. With small neighborhoods (nine neighbors), agents are more likely to express dissent than with a thoroughly mixed population (more than 81 neighbors), *but* that dissent is not very likely to spread (the mode, as seen in Figure 9, was only around 36 dissenters or 30 percent opposition). With a larger neighborhood, public pressure is more likely to quash expressions of dissent, but when a random spatial arrangement permits dissent to be expressed, it proves very contagious.

Kuran (Kuran 1995b:39) discusses how the "publicness" of a preference varies continuously for various groups: "In 1989, a Soviet citizen admitted to having worn 'six faces' under communist repression: 'one for my wife; one, less candid, for my children, just in case they blurted out things heard at home; one for close friends; one for acquaintances; one for colleagues at work; and one for public display'" (Anonymous 1989). The spatial model of dual preferences shows how this might occur, given the different contexts in which a single individual finds himself. This would not include the effect of anonymity at a great distance from friends and close colleagues, since each increasing neighborhood size has smaller neighborhood sizes nested within it. Further, in my model, an agent's publicly revealed preference would be seen to flip-flop in expanding circles of influence. An elaboration would have to

include a consistency requirement if the neighborhoods were nested, or a function to determine who could be trusted with the knowledge that the agent is changing his public preference in different contexts. In such a model, a person would know pretty well the private opinion of those closest to him, but as the social distance increases he will be less sure of the information, except to know that it is more likely to be falsified. Actually, he would not know even that with certainty, since information from actors at some distance could be sincere or falsified. An agent would always wonder if he were in an enclave. Actually, since close acquaintances will see all levels of preference expression, they can make several kinds of hypotheses. What will they be able to figure out?

1. They will be able to make an estimate of the private preferences of the individuals around them. They will have the most information about those closest to them.
2. They will be able to supplement their own information about public opinion, because they will see how others behave in public.
3. They will exercise a certain amount of power because of their knowledge about private preferences of those closest to them.

We will find that individual behavior depends to a great extent on whether the sets of social networks are nested or non-nested (because with nested sets it may be important to remain consistent across spheres), and what the social costs of dissent are for each set. For example, we can imagine a setting where the greatest costs to dissent are in the home, whereas in the marketplace, anonymity provides a lower cost to dissent (or, as is more likely, where the tendency to falsify preferences is reversed because of prevailing opinions). Since homes are more likely to be homogeneous, dissent may be more costly at home.

Conclusion

The models of Heiner and Kuran, while at different ends of the individual versus collective behavior spectrum, both deal with complex issues of surprise, thresholds of behavior change, conservatism, and the role of history. They both show that when confronted with environmental complexity, the response of

economizing agents may not be to be more flexible but less—to depend, when in doubt, on tried and true, reliable behavior, or on majority opinion.

Milon and Boggess (1988) point out an important implication of reliability theory: agents will ignore complex or non-local information, even when it is costless to acquire. Heiner explicitly applies this implication to the evolution of large, complex social systems, where it becomes difficult to monitor the joint behavior of all the actors. A boundedly rational agent will decide on ways to limit the choices they are confronting, and one way is by limiting the information set to a local neighborhood with which the agent is more competent. But this is just the situation in the dual preference neighborhood model above. Although it is rational to limit information gathering to a local neighborhood, there are instances where this can give incomplete results, as we have shown.

For our purposes, the implication of these kinds of social processes is that narrowly rational, optimizing behavior may be neither observed nor prescribed for problems of ecological management. More complex social processes such as have been described in this chapter open up an important role for political behavior. As we shall see in the next chapter, a more complex understanding of ecosystems also creates new opportunities and new issues that require an understanding of social and political processes.

POLITICAL ECONOMY OF RESILIENCE

Understanding the political economic dimensions of ecological problems can have its starting point in social structures and processes, or in ecological concepts. I have chosen to organize this chapter around ecological concepts to emphasize how recent changes in ecological theory and understanding impacts on political economic processes, and how these social processes can enlighten the search for better ecological policies. I suggest that ecological understanding has advanced in phases[27], and that each phase has opened the door for examining the salience of an increasing number of social processes.

The "Old Ecology"

What writers have called the "old ecology" of course did not become old until a new set of problems emerged and gained attention. In announcing the advent of the "new ecology" described below, writers have diagnosed the old ecology as preoccupied with systems at equilibrium or steady state. The climax composition and structure of ecosystems was seen as determined by the suite of environmental driving forces (including such forces as insolation, biotemperature, rainfall or water availability, nutrient availability, etc.; Thornthwaite 1933, Holdridge 1947, Whittaker 1975, Guetter and Kutzbach, 1990), Energy flows and material cycles of various kinds set a limit on the number, organization, and diversity of organisms in an ecosystem. Ecological problems, in general, involved some sort of disturbance from that steady state, and when the disturbance was removed, the system could return to the former steady state. The disturbance could take the form of pollution, land-cover conversion (deforestation for example), extraction (fishing, timber harvesting). The seemingly plausible assumption, common to linear or

[27] With co-authors I have argued elsewhere that understanding the relationship between ecological management institutions and ecosystems can be furthered by a threefold typology of ecological problems (Folke et al. 1998): (1) issues raised by considering ecosystems as life-support systems, (2) issues raised by considering ecosystems as complex, adaptive systems, and (3) issues raised by the driving forces and disturbance processes which shape ecosystems. Here I lean on that conceptual organization.

continuous models, is that a small change in human pressure on ecosystems would result in a small deviation from steady-state conditions, and that large changes in ecosystems must result from large human pressures.[28] The concept of a one-to-one mapping between ecosystem steady states and a "signature" or *biotope* of driving forces could even be extended to include anthropogenic forces (Odum 1983:96).

A somewhat stronger version of the steady-state approach considers ecosystems as a kind of super-organism, with a deterministic development trajectory not unlike an organism as it is born, develops, and comes to maturity. This view of ecosystems is typically attributed to Clements, but finds its best expression in the work of E.P. Odum, whose 1969 *Science* article, "The Strategy of Ecosystem Development" outlines the logic of ecosystem succession in a clearly functionalist manner (Odum 1969). This view is more sophisticated because it recognizes a *pathway* rather than a single ecosystem *state*, but it still implies that ecosystem development leads inexorably to a pre-determined climax. They may be temporarily disturbed or be arrested part way through the development pathway, but when the disturbance or hurdle is removed, the forcing functions impinging on the system will restore the natural equilibrium.

The relationship between society and nature was not seen as materially complex. Along with the development of ecological science came a growing awareness that ecological systems, together with the geological systems that provide metals, minerals and fossil fuels, compose a life-support system for the planet. As humans extract and enjoy services from ecosystems, they disturb or consume them. The level of service provided by the ecosystem could be expected to vary smoothly with the level of disturbance or use.

In any case, ecological models that postulate single, stable equilibria have quite straightforward management and policy implications. Renewable resource systems with well-behaved properties (such as sigmoid growth curves) can be managed for maximum sustained yield (defined in either economic or material terms), adjusted for market prices, costs of harvest, and predictable climatic effects on growth rates, recruitment, carrying capacity, etc. The optimum harvest or extraction rate could be argued, but the idea that there was a calculable optimum was not much questioned.

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[28] The plausibility derives in part from a fundamental predisposition in human inferential processes, called the "representativeness" heuristic (Tversky and Kahneman 1974).

Herman Daly, for example, has argued that the economy is oversized relative to the natural systems which support, and that there is therefore unsustainable "throughput" (Daly 1974, 1979). For Daly, "scale" is shorthand for "the physical scale or size of the human presence in the ecosystem, as measured by population time per capita resource use" (Daly 1991). Daly uses the analogy of the Plimsoll mark on boats. A badly allocated cargo will cause the ship to hit the Plimsoll line sooner, but even an optimally allocated cargo, if it exceeds the Plimsoll line, will cause the ship to sink (though it may sink optimally). Daly discusses two kinds of optimal scale:

1. The anthropocentric optimum. The scale of economic production is expanded to the point where marginal costs in sacrificed natural capital equal marginal benefits, both as valued by humans. Other species and systems are valued only instrumentally.

2. The biocentric optimum. The same method (equating marginal benefits with marginal costs) is used, but the intrinsic value of other species is taken into account. Since this value is positive, it raises the marginal costs of expansion. Therefore, the biocentric optimum is smaller than the anthropocentric optimum.

What Daly does not question is the existence of an optimum. Ecological processes carry on "naturally," with greater or lesser room based on human decisions about optimal scales.

If ecological processes could be summarized in a production function, to fit into a economic model, then any political or institutional complexity would revolve more around social relations and interactions than ecological ones. Ecological and political issues would be, to a great degree, separable.[29] Whether or not to reduce the size of the economy relative to the size of the biosphere may be a political question, but the response of ecological systems to release is taken as given.

If social and ecological issues are seen as separable, then it makes sense to look, in general, to one or the other for causes of environmental problems. As such, many theories about environment-society interactions tend to be humanist or ecologically determinist (Sanderson and Pritchard 1993). This

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[29] That is not to say that there could not be great disagreements over growth rates, limits to growth, optimum resource throughput for society, or the distribution of benefits from ecosystem services. But it could be argued that most arguments would boil down to disagreement over ecological systems or social/political systems, but not about co-evolved systems.

typically optimist/pessimist dichotomy is enshrined in the famous Simon-Ehrlich debate and wager about commodity prices for a suite of five metals.

Paul Richards, while rejecting the idea of "grandiose adaptive systems theories," notes several useful, general categories of models for interpreting the ecology of disease in Africa. Two of them are the sort of old-fashioned, monocausal kinds of models characterized above as ecological determinist or humanist. The first Richards calls the "intrinsic unhealthiness" model—it conveys a sense of environmental determinism in that tropical Africa is seen as a zone of inherent physical risk.[30] The second style of model emphasized contact with the rest of the world through trade, colonization, transportation, migration and mobility; Richards calls this the "increasing unhealthiness" model, and he associates it with modernization/dependency theories. Driving forces in the first sort of model are environmental, but in the second sort human forces are the drivers of change, and the environment simply forms the backdrop against which the human/social drama unfolds.[31] In both cases, causes are sought in *either* the physical or the social realm, but not in their *interaction*.

The "New Ecology": Upsetting the Balance of Nature

The emergence of the "new ecology" means for some that environmentalists have done an "end run" around the old problems of resource depletion, cumulative effects of pollution, and limits to growth. A new set of issues has more to do with ecosystem organization and structure than it has to do with energy and materials flows. The problems that have been identified as the domain of the "new ecology" make ecosystems historically, spatially, and socially contingent:

(1) Ecosystems are dynamic ("change is the only constant").

(2) Ecosystems are spatially heterogeneous ("all ecology is local")

(3) Humans are part of ecosystems ("we are everywhere")

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[30] According to the typical model, the resultant underpopulation hinders development along Boserupian lines (see Boserup 1965) by avoiding the population pressure necessary for agricultural intensification (Richards 1983:14).

[31] Richards identifies a third type of model, more typical of "new ecology" approaches, which I describe later.

The consequences of this shift in perspective are easily recognized, and they may impact on human behavior through tactical, strategic, and imaginary pathways. The implications of the three premises may be characterized as (1) there is no baseline, (2) one cannot generalize, (3) there is no nature "out there."

"Change is the Only Constant"

The received "new ecology" holds that ecosystems are dynamic entities and that there is no such thing as the "balance of nature." Wiener's interpretation is that the new ecology substitutes the vision of "nature resting in harmonious equilibrium" with "restive nature—in perpetual flux, disturbance, and renewal." According to Wiener (1996),

> Law cannot provide a "balance of flora and fauna" not because it would be too difficult, but because the term is meaningless: populations of various organisms are perpetually in flux, landscapes change, climates change, and definitions of species and ecosystems change (p. 11).

Profeta (1996) writes about the "chaotic behavior" of ecosystems, leading to "inherent unknowability." Without a sense that there is any "normal" state for ecosystems, the idea that "natural" systems can form a baseline for understanding disturbed system loses salience.

"All Ecology is Local"

New ecology, as described by Botkin and his commentators, holds that spatial pattern is highly path dependent, and that generalization between two currently similar ecosystems may not imply that their future paths will be similar.

I described above the two monocausal models types considered by Paul Richards for the ecology of disease in Africa. He notes a third type of model—what he calls a "dynamic ecosystems approach"—which clearly exhibits the properties of "new ecology" problems. His third type deals with "surprise" epidemics of diseases in places where they have long been established, and with epidemics associated with the settlement frontier. Drawing on the work of John Ford (1971), he outlines a model of changing spatial and temporal interactions between disease strains and their host organisms, the evolution of resistance, and ecological change. Richards extends his description with an explicit critique of colonial attempts to

control sleeping sickness and river blindness based on "universal and ultimate solutions" instead of building on local strategies based on "particularist ecological management" (Richards 1983:22).[32]

It is also extremely difficult to assess the representativity of cases. In spatial terms, research has found unexpected but important heterogeneity at small scales. Work on land-use and land-cover change in the Brazilian Amazon suggests that in order to convey the heterogeneity of local-scale land use, remote sensing samples must exceed 90 percent of the areal extent of the basin (David Skole, personal communication). Christine Padoch and Wil de Jong (1992) have found extraordinary diversity of land use in a small, apparently homogeneous riverine settlement in the Peruvian Amazon and linked it to broader observations about the region. Likewise, there have been spectacular over-generalizations in the tropics, characterizing floodplain vs. uplands, and provoking powerful arguments between students of the same ecosystem over questions of diversity and human ecology (Moran 1991, Coomes 1992). Much of the important heterogeneity in tropical soils has been overlooked due to lack of research and over-reliance on temperate zone experience (Richter and Babbar 1991)

"We Are Everywhere"

The first two components of the "new ecology" can be taken as objective critiques of ecological science, and it can be argued that answers may be found in a reformed, enlightened (even humbled) ecological method (see below). The third component is more radical, and may form a more fundamental critique of current management policy and politics. The new ecology claims that people are a part of nature: that it is wrong to see nature as "out there," as the stage for human activity, and as the control for our experiments in ecological management. [33]

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[32] Richards generates essentially the same critique of what he sees as over-generalizations in colonial and developmentalist prescriptions for agricultural modernization in Africa (see 1983:40-41).

[33] Ecological management policies for parks and protected areas in North America frequently use as a standard that ecosystems should be maintained in the "natural" state they exhibited before the arrival of Europeans. Of course this ignores or diminishes the role of Native Americans in creating those ecosystems (Denevan 1992), or else implies that they, and not Europeans, are "part of nature." More recently, some have attempted to rehabilitate the standard by contrasting rates of anthropogenic change before and after

Wiener (1996) argues strongly that people are a "part of nature," but he cautions against injudicious use of the term "natural": in particular he notes the way "natural" is used to justify certain power relationships ("natural" rights of landowners), or to give an ethically normative dimension to a certain phenomenon ("natural" role of women, or for the economist, the "natural" rate of unemployment.). These dangers are reiterated in the same volume by Kuhlmann, who argues that redefining ecosystems to include people weakens protection. He warns that the concepts of the new ecology are appropriated by extraction-oriented managers and politicians, giving the example of how "ecosystem management" has been defined by the federal government to include people and their uses, so that it becomes hard to imagine ecosystems *without* people in them (Kuhlmann 1996).

Wiener describes what he calls the four faces of environmental law. His (modified) table is reproduced below (Table 2). The chief attribute dividing his "holist" from his "separatist" faces is, of course, how human-nature relations are viewed. Wiener would not argue that there is middle ground between the various faces. For example, in what may be seen as an combination of the second and third positions (separatist-stewardship and separatist-taint), some would argue that not *all* humans are morally inferior to nature. The distinguishing features of *good* people are variously (1) long experience with a set of ecosystems; (2) a claim to being "local," "traditional," or "indigenous" (but especially local); and/or (3) status as a pre-capitalist society oppressed or threatened by industrial/capitalist development ("ecosystem people" as opposed to "biosphere people"; Berkes and Folke 1994). These characteristics, not coincidentally, mesh nicely with the three tenets of "new ecology," thus they provide a kind of self-regarding confirmation of "good" management. In other words, if managers (1) have sufficient temporal experience to understand complex ecosystem dynamics, (2) are sufficiently "local" to have in-depth, spatially-appropriate knowledge of ecosystem patterns, and (3) believe that they are "part" of the ecosystem (that is they don't subscribe to the "Western" human-nature dichotomy), they qualify as good managers.

European settlement (Frampton 1996). This implies that Native American management was *more* in harmony with nature than European management—an implication contestable both on theoretical and empirical grounds.

Table 2. Wiener's four faces of environmental law

Parameters	1 Separatist-dominion	2 Separatist-stewardship	3 Separatist-taint	4 Holist
View of nature	Stable, vast and resilient, raw, fearsome	Stable, in balance (absent human disruption); fragile; wild	Stable, in balance (absent human disruption); fragile; pristine	Dynamic, in disequilibrium, inter-connected, chaotic
Human-nature relation	Separate	Separate	Separate	Not separate
Moral status of humans	Superior to nature	Superior to nature	Inferior to nature	Morally uncertain
Role of law	Exercise human dominion over nature; exploit	Exercise benign stewardship over nature; conserve	Protect balance of nature, untainted by humans; preserve	?

Source: Modified from Wiener 1996:4 Table 1.

Dove (1992) argues that there is a fundamental resistance to considering culture and nature together; there is a sense in which both carefully constructed categories become polluted, and therefore repugnant and even embarrassing (Douglas 1992). In an afterword to an article discussing the history of the word "jungle" and how it describes anthropogenic landscapes, Dove offers the following commentary (Dove 1992:252-253):

> At the end of a study that argues for the existence of "weedy" species of macaques that have evolved in anthropogenic environments, the authors offer the following provocative critique of their science:
>
> "When a monkey being focal-samples snatches yesterday's chapati [unleavened bread] off the garbage dump, in our experience it is much easier to be embarrassed than it is to think seriously about the historical, biogeographical, ecological and behavioral implications of the act" (Richard, Goldstein, and Dewar 1989:588).
>
> The interrelations between nature and culture have, indeed, tended to fall into the "cracks" of scientific study. They are infrequently studied; they are deemed, by implication, not fitting for study. Their ambiguous status—neither nature nor culture, neither fish nor fowl—makes scientists uncomfortable with them, in the same way that natural symbols which cross categories have always made people uncomfortable (cf. Douglas 1966). When scientists are forced to confront their existence, as when a monkey under study eats human garbge, the result is embarrassment.
>
> This classificatory embarrassment may once have served some purpose in the scientific community, but today it is clearly a liability. The chapati-eating monkey, like the anthropogenic jungle, is no longer the exception but the norm. This interface between culture and nature is where some of the greatest environmental hazards are posed today and where the potential rewards of scientific understanding may be greatest as well. But

> because muddled categories are embarrassing—and the more muddled, the more embarrassing—these areas of the greatest interrelation between nature and culture often receive the least attention from science. They should receive the most.

If Wiener and Kuhlmann are right about the effects of the new ecology, the lesson has been learned. The only embarrassment remaining after the conquest of the new ecology would be from those who claim that there are distinctions between people and ecosystem.

Beyond the New Ecology: Tools for Understanding

Taken together, the propositions of the new ecology describe a world of constant motion, fluidity, and change that is completely historically and spatially contingent. In fact, the pervasive effect of human activity is, as Dove describes it, not only confusing but embarrassing. Old standards based on the balance of nature, on stability, on overarching generalizations, and on objectivity no longer seem to apply. In reacting to an overly static, equilibrium-centered old ecology, there may be a risk of throwing the baby out with the bathwater. The view may be challenged on two levels. On a materialist level, it may be that systems are complex but not hopelessly contingent and unpredictable. On an ideological level, holding that ecosystems are without equilibrium is but one of many "views of nature" that can be imagined.

Moderately Complex Models of Ecosystems

George Klir has offered a typology of complex systems that captures some of the differences in approach between the Old Ecology and the New (Klir 1985; his typology follows Weaver 1968). For Klir, complexity comes in three varieties:

Organized simplicity. Systems that exhibit organized simplicity can be described with small numbers of variables, and they show a high degree of determinism. Klir argues that this is the traditional purview of science. There are small numbers of significant factors, and a large numbers of negligible factors. Such systems are very amenable to analytical mathematics (particularly linear regression), calculus, and differential equations.

Disorganized complexity. These systems have large numbers of variables, and a high degree of randomness. They may, under the right circumstances, be amenable to statistical methods (the use of

aggregates is appropriate under assumptions of large numbers and randomness). Individual prediction can only be of the probabilistic variety.

These two systems deal only with tiny fractions of the whole complexity spectrum. Largely methodologically ignored is the large range between, called organized complexity.

Organized complexity. "Such systems are rich in factors that cannot be neglected. That is, if they are neglected, the systems lose their relevance as adequate models of the real-world phenomena involved. And, by the same token, they do not involve a sufficient number of entities that are sufficiently random to yield meaningful statistical averages" (Klir 1985). The new ecology describes systems that exhibit organized complexity. Even within the realm of organized complexity, views differ on the role of explanation and prediction, as we shall see.

New Ecology Revised

The world described by Botkin, in response to the organized simplicity of the "old ecology," may be described as disorganized complexity, essentially random, understandable in it details but not in any overall pattern. The claim lends intellectual support to academic positions of particularism and relativism—some of the biggest consumers of the new ecology are post-structural political ecologists wishing to paint establishment science as biased, colonial, and imperialist (see for an example the collection of essays in Leach and Mearns 1996). However, Botkin's new ecology is not the only new ecology around. Another set of writers (with considerable overlap), including C.S. Holling as a leader, stresses that although ecosystems are complex, there are a few general systems principles that can guide understanding, and that can reconcile some contradictory conclusions from other perspectives.[34] Table 3 compares what may be regarded as stereotypes of the three views.

The third approach offers a set of tools for understanding and sorting the contingencies introduced by the New Ecology. Holling (in Holling and Sanderson 1996) notes several "key features" of ecosystem structure and function:

Table 3. Comparing the old ecology and two versions of new ecology.

	"Old Ecology"	Botkin's "New Ecology"	Holling's "New Ecology"
Change	Transient / unidirectional	Constant	Episodic
Pattern		Unique / random	Patchy
Equilibrium	Single	None	Multiple
People and nature	Separate	Part of nature	?

- The environment is not constant. Environmental change is not continuous or gradual, but episodic.... [The] critical processes that structure ecosystems take place at radically different rates covering several orders of magnitude, and these rates cluster around a few dominant frequencies.

- The spatial organization of natural systems is not uniform either. Nor is it the same at different scales. Ecolgoical systems are "patchy" at all scales—from the leaf, to the landscape, to the planet.... Therefore, scaling up from small to large cannot be a process of simple aggregation: nonlinear processes organize a shift from one range of scale to another.

- Ecosystems do not have a single equilibrium. Rather, multiple equilibria define functionally different states, and movement between these states is a natural part of maintaining structure and diversity. On one hand, destabilizing forces are important in maintaining diversity, resilience, and opportunity. On the other hand, stabilizing forces are important in maintaining productivity and biogeochemical cycles.

Scales

Two of the distinguishing features of the new ecology *sensu* Holling are references to distinct scales of processes and a limited set of steady states. These emphases permit a faithfulness to observed natural variability while still postulating an understandable set of organizing driving forces. The question of scales is a continual thorn, but essential to the understanding of environmental change (Turner et al. 1995). The approach described above recommends that rather than arbitrarily stipulating scales of analysis, we should derive them empirically.

The conventional thinking on scales emphasizes finding the right scale, rather than arbitrarily imposing scales. This has often been operationalized as a preference for working at multiple scales, corresponding to the diversity of processes and driving forces. Working at multiple scales, however, has

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34 Often associated with the latter perspective is a set of scientists who, under the auspices of the Beijer International Institute for Ecological Economics, created a loose network for describing systems that

frequently been reduced to farming out research at different scales to different researchers, then compiling the results in an edited volume and calling it multi-scale analysis. Innovative working at multiple scales involves crossing and linking scales-not just multiple scale analysis, but inter-scale analysis.

As has been said in reference to nested scales, "the world is not a set of Chinese boxes."[35] Static approaches to hierarchy theory are satisfied with a snapshot of processes describing the scales at which they operate. In the real world, it is found that these scales change over time. Many of the problems and processes to be addressed have characteristic time periods which are speeding up, or spatial scales which are expanding and synchronizing. Or the spatial and temporal scales of an economic or ecosystem process may change in both directions over the course of landscape evolution. Contagious processes are an example: fragmented forests with small-scale patches may be relatively immune to disastrous fire or disease outbreak, however, as they age they may converge in flammability because of accumulating litter loads. As the characteristic spatial scale of the system increases, so does the potential for catastrophic fire. An important component of scale-sensitive research is to explain how this occurs, and to develop new ways of modeling systems whose fundamental underlying structure is changing over time. The test of a good model may not be whether it is successful in predicting particular environmental change consequences, but whether it helps in understanding the importance of changes in the structure of the system in question.

The set of issues raised by hierarchy theory both complexifies and simplifies problems of environmental and social change (see Table 4). The problem of scale applies to our observation regime or frame of reference: what is the time step and duration of observations, and what is their resolution and extent? The same questions can be asked about the model we are using to describe the processes we are observing, and (more fundamentally) about the scales of the processes themselves. Most discussions about scales revolve around the first two objects, and the point of the discussion is to make comparable observations and models. The innovation is to be asking those questions about scales of ecosystem or economic processes themselves. This allows the researcher to probe deeper—to think about why scale

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exhibit multiple equilibria, called the Resilience Network.

[35] Anna Tsing, personal communication.

breaks exist, and what the linkages are between scales of processes. The implication is that processes that operate on similar scales, either spatially or temporally, are more likely to have important interactions. The oft-noted example is of political systems that are driven by the time-scale of the electoral process, which allows them to ignore more slowly changing but important processes in society.

Table 4. Consideration of scales in scientific explanation

Object for which "scale matters"	Issues
Observation	Describing scales
Model	Linking across and between scales
Reality	Explaining scale breaks

Human time scales are generally handled in economics through the use of discount rates—for simplicity and analytical tractability, these often have the underlying assumption that events in the future (or at a distance) are smoothly discounted, or are all discounted at the same rate (by reducing the consequences to a utility metric). They will tend to ignore discontinuities or inflection points in discounting that may occur if there are discrete time or space horizons, as we would expect to be the case where there are meso-scale political and social institutions. A related implication is that actors (individuals, or organizations) may have a characteristic "window of observation" on phenomena, and that processes occurring outside that window are ignored. In temporal terms, these would be processes either so fast that they are only observed as averages, or so slow that they are not detected, or so rare that they have not registered (Crumley 1994, Simon 1973). In spatial terms, these are processes that occur on such a fine scale that they average out, or on such a broad scale that they aren't noticed.

One implication of the scale problem is this: Because of problems crossing scales, the idea that we can identify a good policy lever to affect environmental change loses credibility. By the time the dynamics of drivers at one scale are estimated, policy consequences at other scales may well have changed. It is also possible that cross-scale manipulation is too complicated or blunt an instrument anyway, as in the case where all land use change is driven by local terms of trade instead of international terms of trade, for example.

Competing views of nature

Holling has proposed that humans view ecosystems through their own biases and cultural filters, but that there often ecosystem attributes which reinforce these interpretations. He has suggested four ways in which it is possible to view nature, and suggests that these account for a great deal of the variability in both scholarly and popular understandings (Holling 1993).[36] They can be described graphically through the often-used ball-and-cup diagrams which show stability properties of dynamical systems (see Figure 10).

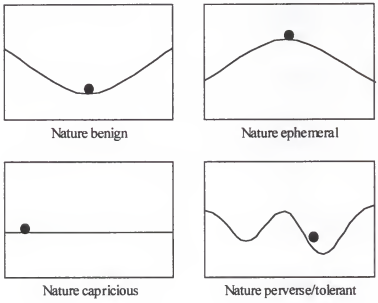

Figure 10. Holling's four views of nature.

The first view, Nature Benign, is another way of describing the Balance of Nature—there is a single equilibrium, the way nature exists "normally" or "naturally." It is possible to disturb such a system, even to exploit it for some period of time, but when the disturbance is removed the system returns to normal. A

[36] The paternity of the typology is actually more complicated. Holling (1986) originally produced a threefold categorization; the fourth ("Nature capricious") was generated by Schwarz and Thompson (1990), which accounts for the neat way the views of nature correlate with Cultural Theory categories. Holling has since adopted the fourth.

variant on that view is Nature Ephemeral. In this view, nature is also in balance, but it is a delicate balance. Any sort of disturbance or intrusion is likely to destroy the delicate Balance of Nature, with disastrous results. Nature Capricious is the existentialist view among the four. Nature is what it is, it has great inertia, if disturbed it has no tendency to either crash or to return to its previous state. This is the view of nature that one finds in some of the consumers of the New Ecology (Profeta, for example). The last view, Nature Perverse/Tolerant, is the closest to the idea of ecological resilience—that there are multiple (but a finite number of) equilibria, that small disturbances away from an equilibrium may not result in long-term change, but larger disturbances can shift the system into an alternate stability domain.

Michael Thompson has connected these four views to the four "cultures" or "ways of life" of Cultural Theory. Cultural Theory has been used as an alternative to strictly economical methodologies for modeling social processes in several major global change projects, both at the Bureau for Environmental Assessment (RIVM) in the Netherlands (Janssen 1998) and at the Pacific Northwest National Laboratory (Rayner and Malone 1998). Michael Thompson's characterization of the four cultures is found in Table 5.

According to Thompson, the four solidarities are scale independent; that is, at any level of human organization, actors may participate in one of the four cultures. The choice of four (or five) cultures may be criticized as arbitrary, but there are historical reasons for the typology. The anthropologist Mary Douglas was the creator of the typology; she used a two-axis matrix of culture attributes to describe social organization—with the dimensions of *grid* and *group* (see Douglas 1970). And, working independently of cultural theorists, psychologist Alan Fiske has proposed essentially parallel categories that he considers fundamental psychological forms of sociality (Fiske 1992).

What the views describe is a set of attitudes toward nature (and toward social forms of organization) which are heterogeneous without being infinitely variable (Jasanoff and Wynne 1998). By associating the four cultures with four views of nature, Thompson and Holling suggest two things: (a) that certain kinds of environments lend themselves to certain kinds of management techniques or certain kinds of social relationships, and (b) that certain cultures are predisposed to certain models of ecological reality. What is needed is a set of more formal models that describe the interactions between the cultures of cultural theory, and the self-reinforcing processes that serve to maintain the distinctions (Wildavsky 1987). In

itself, Cultural Theory has offered no credible account of the emergence of the various "ways of life," and no theoretically satisfying reason why there should be four and not five, six, or a dozen.

Table 5. The four cultures of "cultural theory"

	Individualist	Hierarchist	Egalitarian	Fatalist
Human nature	Self-seeking	Bad but restrainable or malleable	Caring and cooperative	Fickle
Physical nature	Benign (globally stable)	Perverse/tolerant (limits to stability)	Ephemeral (overconnected, subject to collapse)	Capricious (no rhyme or reason)
Management style	Independence	Run by experts	Participatory Response to crisis	Independence Response to boom in external sector
Cooperation	Bilateral bargains, decentralized nexus	Coercion/submission	Consensus	None
Externalities	Low	Limited, solvable, require incentives for cooperation	Pervasive, requires unanimous cooperation?	Pervasive and unmanageable
Sense of time	Discounted future, "anchor the present in the future"	Long, "chain the future to the past"	Foreshortened and undiscounted	Short, future is unknowable
Social welfare/utility	Undefined	? Possibly orthographic	Leontief	Linear
Institutions	Market	State (in general sense)	Shame, cooperation	??

Sources: Wildavsky 1991, Thompson 1997

		Group	
		Low	High
Grid	High	fatalist	hierarchist
	Low	individualist	egalitarian

Figure 11. Mary Douglas's four cultures. *Group* describes the degree of collectivization, and *grid* describes the degree of social structure (typically inequality).

Four box heuristic

The four views of nature suggested by Holling do not make up a post-modern view of the world, where different observers describe completely different but equally valid impressions of nature. For Holling, the four different models correspond to materially real ecosystem dynamics (although the models may be held

by humans even when they are no longer valid descriptions of the system). Each of the views is partial in that it describes ecosystem dynamics at a particular period in time. Holling has his own general model which incorporates each of these submodels, a cyclical view of ecosystem dynamics which he calls the adaptive cycle (Holling 1995).[37] The four-box model is shown in Figure 12.

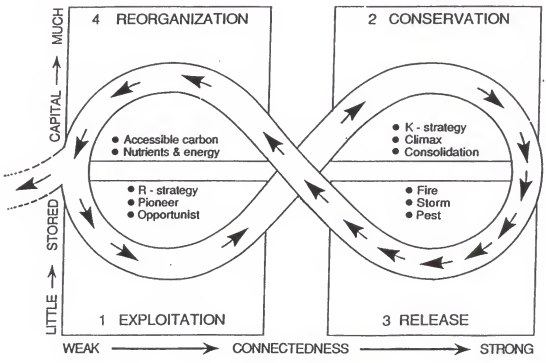

Figure 12. The four periods in the "adaptive ecosystem cycle." From Figure 1.2 of Holling 1995.

Implications of the "New Ecology" for Natural Resource Management

Much has been written about the implications of the new ecology for natural resource management—both about the hyper-contingent systems described by Botkin and about the more organized complex systems described by Holling. One author summed up the implications of the new ecology nicely: "A

[37] Calling the four-box model an "adaptive" cycle is clearly a normative judgment, and may have political

central feature ... is the messiness of ecosystem management" (Frampton 1996). Describing how systems deal with the mess, and how they ought to deal with it, is a subject of some controversy. Most prescriptions tend to fall into categories that call for either more or less centralized understanding, and that is a useful initial typology. Some recommend expert analysis and professional management, whereas others describe a decentralized and participatory approach that give a wide variety of stakeholders "ownership" of the problem. Even within these categories, a certain amount of mythology impels many of the conclusions—not mythology in the sense of untruth, but mythology as a set of organizing ideas. Of the two main myths, one tends toward monotheism, while the other is more pantheistic.

The first myth requires that complexity be addressed by science in its finest form. In some versions it requires a revolution in science to embrace the new ecology, while in other versions it requires only incremental improvement. The scale of complexity can only be understood and managed at a large scale, using the integrative capacity of scientific understanding to harmonize conflicting details arising at lower levels. Despite the scale of engagement, human management must remain light on its feet—it must be flexible, adaptive, and responsive to new information. Local people (amateur scientists) may be well meaning and sincere (although they may not be), but they can be fooled by the environment and by their own behavior.

The second myth, while maintaining that the truth is "out there," holds that it can be known best on an intimate level, by local people, in their local environment. Such knowledge is developed in relative isolation over long periods of time. Decentralized understanding of nature needs to be protected from, rather than integrated into, centralized and standardized political and scientific institutions. Interestingly, many adherents to this myth view the market with suspicion, despite its decentralized nature. Larger scale forces, like national governments, tend to have suspicious motives as they interface with the environment and with local communities.

While representatives of each myth can be found, many writers are syncretists who advocate either a balance or a combination of the two perpectives. They are more likely to recommend a hierarchy of engagements with ecosystem complexity, from local to global levels, to take advantage of the unique

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implications as described elsewhere in this chapter.

attributes that lead to optimal management at each level. The target of such multi-scalar ecosystem management is implicitly a kind of "harmony" or "fit" between human and natural systems, and between levels of the hierarchy (Folke et al. 1998).

Other powerful ideas which pervade writings about the new ecology are the search for "win-win solutions," the role of "citizen science," and the notions of "community" and "sustainability" as touchstone for all manner of beneficial innovations and interventions. There are some overarching themes that unite most of these prescriptions for economic or institutional innovation in the face of environmental complexity, and a few differences, as noted above.

One of the main things they have in common is a systems perspective. A common prescription is that there must be effective feedback mechanisms from environment to society, and between elements of society; that is, open feedback loops must be closed (Levin et al. 1998:232) and loose ones tightened (p. 230). There must be a coupling of stimulus and response: only then will systems be flexible and adaptive. The general idea is to create the proper feedback loops, tinker with and adjust them, and then set the "system" off to operate unattended. It is after all "a system" which has self-organized—if the self-organized state is unacceptable, then some sort of adjustment will make it right. If the environmental problem is based on market failure, then fix the market. For example, in one Beijer Institute paper, the problem of economic growth was fundamentally unchallenged. The authors expressed confidence in being able to use the system: "If we hope to use market forces to achieve broader goals..." (Levin et al. 1998: 230). Inappropriate prices and missing markets are the usual suspects in market failure. Although the authors are careful to specify that simplistic private property rights are not a cure all for environmental problems, they are clearly a solution of first resort.

In the same paper there is an uncritical transfer of the idea of *ecological* resilience to society, whether thought of in terms of local communities or national economies. Just as it is assumed that ecosystems, if they exist, must have acquired *some* degree of resilience to natural environmental fluctuations[38], there is the notion that communities and economies, *if they exist*, must have been selected for their resilience to

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38 "Every natural system is subject to regular disturbances; those that have survived indeed *must have* built up some degree of resilience" (Levin et al. 1998:228).

perturbation. There is an inherent functionalism in such arguments, as well as a tendency to ascribe normative properties to the observed resilience (although lately more researchers are at pains to point out that bad systems can be resilient to disturbance as well—see Levin et al. 1998).

The key feature that most of the prescriptions of ecologists and economists have in common is a kind of anti-politics. At its extreme, for adherents of the first myth, the recommendation for the use of expert science (Profeta 1996) and for removing many decisions from politics to non-elected professionals (Blinder 1997) decries the polluting effects of politics, the myopia of democratic government, and the muddling of policy-decisions by special interest groups. At the other extreme of local bias, anti-politics finds its expression in calls for community-building and consensus which frequently ignore the political implications of community interactions (see for example the strange effects of pressure for consensus on community interactions in the dual preference model from the preceding chapter). The search for "win-win" scenarios, with its focus on Pareto-efficiency, prevents the discussion of power in social interactions. The exercise of power implies that there are winners and losers, at least relative to a set of expected outcomes. Some have postulated that the economistic obsession with economic growth is a way of avoiding messy political issues.[39] If, however, there are true redistributional issues at play in most decisions about institutions, then constructing win-win solutions may be as much about manipulating perceptions as about finding truly Pareto-safe moves (see previous chapter).

Another factor most ecological and economic prescriptions have in common is a generic treatment of affected agents. Actors in most models, whether they lean on the large scale myth or the small scale myth, show a fundamental homogeneity of interest, wealth, rationality, and other features. They may be differentiated by sector and treated as representative types, to account for differences in their behavioral engagement with nature, but there is little inter-sectoral differentiation that would lead to political

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[39] In his discussion of non-zero sum games, Maier (1987) points out that a shared characteristic of liberal productivist and fascist (and national socialist) regimes was the concept of non-zero sum social organization. Liberal productivism held that there was a "best way" to organize society based on concepts of efficiency, to harmonize competing interests (which resulted from misunderstanding). In contrast, non-utopian liberal concepts included notions of trade-offs, but held to the primacy of guaranteeing individual freedoms. The utopians suggested no-one need lose in a liberal regime. The fascists and Nazis went further and held that only real losers would lose, those that deserved to.

conflict. In community level models, what is in the public interest is also typically considered to be in the private interest of everyone (Leach et al. 1997). If people have different interests, this may not be the case.

Toward a Political Understanding

Most of the prescriptions derived from the advice of economists and ecologists can be described as "utilitarian," that is, it is concerned with optimizing some notion of social welfare, without much regard to the issues of distribution, ideology, or power. This is a conscious decision on the part of many. Whether or not ecosystems are understandably or incomprehensibly complex, the previous standards for judging the success of ecological management have collapsed. No longer is it possible to judge ecological management against the standard of the "balance of nature," nor is it possible to think of "nature" without anthropogenic structuring forces. How then can management be assessed? Several writers have explicitly recommended a *consequentialist* approach. Wiener (1996) states, "The human/nature dualism in environmental law is the conceptual counterpart of the act/omission dualism in tort law, and we are now...beginning to construct a legal regime that escapes this dichotomy and is based instead on *consequences* and on incentives to promote ecological health" (my italics). Without commenting on the problematic notion of "ecological health," we can detect in Wiener's statement a disapproval of process-based standards for ecosystem management. With the breakdown of the human/nature dichotomy, who is to say what is right and wrong, appropriate or inappropriate, except as measured by ecological impacts? Wiener seems to imply that there are no rules in ecological management.

However, just as the notion of path-dependence in ecosystems and economic systems teaches us that consequences and processes are related, we find that the stability and legitimacy of outcomes in social systems depends on the perceptions that are generated about process (Katz 1996). Human behavior is not strictly outcome-oriented, even though economists tend to treat it as if it were. There are a wider array of human motives than maximizing social welfare (or even maximizing individual welfare). People are concerned with the way ends are achieved, with the underlying fairness and equity of social interactions, and with the manner in which power is brought to bear on decisions.

It is useful to make a distinction between the kinds of problems that can be resolved by consequentialist arguments and those that go to more fundamental issues, necessitating a deontological approach. The first set of issues can be handled with an economic approach, even though the issues themselves and the social dynamics can be described in substance as political. The second set of issues do not find their solutions in merely economic discourse, because they touch on problems that have less to do with optimizing and adjusting, and more to do with norms and values (which are non-consequentialist; Knight 1992:15). Such concerns are more in the province of politics than economics—but this distinction is a methodological rather than a substantial distinction.

To make this kind of distinction, I rely on the typology of problems given in Caporaso and Levine's work *Theories of political economy* (1992). They distinguish economics and politics along methodological as well as substantial terms. In a defense of the role of politics in understanding natural resource management decisions, Sanderson has characterized approaches that draw on economic methodology to address political issues as "infra-political" (Sanderson and Pritchard 1998), more touching on issues of optimal organization than on power and its application.

We can use this distinction to define the sections in the remainder of this chapter. Politics with a small "p" addresses those kinds of issues that Sanderson considers infra-political, in particular, the problem of fit between ecosystem and institutions. Politics with a capital "P" addresses issues that are often neglected by ecologists and economists when writing about ecosystem management, but which are more in the traditional domain of political science.

Politics with a Small "p"

Even economists agree that not all cases of resource degradation are due to wrong prices and missing markets. Underlying markets are institutions which govern property systems, provide for monitoring and feedback of ecological conditions, provide arenas for conflict resolution, represent interests to outside groups and other hierarchical levels, etc. By considering social institutions as real (and not simply as the confluence of individual interests) allows us to ask the question, "what is the purpose of this institution?" as if there were a conscious design behind it that we can plainly see. We can treat institutions as if their

purpose is to solve social problems, and try to discover how to make them function better. This is, for example, a fundamental goal of the Institutional Dimensions of Global Change Project (Young and Underdal 1997). This provides us with a fairly concrete problem set, as well as a well-defined metric of success for institutional tinkering (better social and ecological outcomes). Such an approach is not uncontroversial, as we will see in the next section of this chapter. It is worth exploring in its own right, however, even if it must be modified by addressing some of its functionalist problems.

Table 6. Economics and politics as method and substance

	SUBSTANCE	
	Economics	Politics
METHODS	(1)	(2)
Economics	traditional economic theory; maximizing behavior in market settings, price theory, allocative efficiency	application of economic method to politics; public choice
Politics	(3)	(4)
	application of political methods to economics; power-distributional analysis within market settings	traditional political science; power-distributional analysis within political arena

Source: Caporaso and Levine 1992.

The Problem of Fit

Young and Underdal (1997) characterized the problem of institutional appropriateness in particular environmental (and meta-institutional) contexts as a "problem of fit." Certainly the mind leaps to issues of size, and asks whether a particular institution covers the necessary spatial range of an environmental problem (as may be the case with migratory animals), or the necessary termporal scales (as may be the case with insurance against periodic disasters). The question becomes, is the institution appropriate for its environmental context?

For example, Lee (1993) reduces the institutional problem of overexploitation to a mismatch of scales: "when human responsibility does not match the spatial, temporal, or functional scale of natural phenomena, unsustainable use of resources is likely, and it will persist until the mismatch of scales is

cured." The problem of the commons is seen as a spatial one: the shepherd owns her animals but not the land that nourishes them. The problem is one of getting the scales right.

Functional mismatches are mismatches of scope (also called scale by Lee). Resource users have very specific desires from a highly complex ecosystem, and tend to focus their management actions narrowly. In the area of environmental regulation, bureaucratic micromanagement through command and control policies often cause unintended consequences, or drive the regulated user to search for loopholes. Control may be too broad as well as too narrow. Mismatches of scope may occur when too unwieldy a policy tool is used to manage fine details of a system (for example, manipulating the money supply, which affects the whole economy).

Optimal Scales of Management

The simplest way of thinking about the problem of uncertainty is to ask whether the nature of risk is matched by the scale of institutions. What is the optimal scale at which to manage? There are human organizations at many scales. Given knowledge about environmental variability and resource use variability, is it possible to vest institutional responsibility at the *right scale*? This becomes very similar to the same scale question about scientific understanding from above: what is the right scale at which to study a problem. This question is, what is the right scale at which to *solve* the problem?

One of the limitations of neoclassical economics, with its methodological individualism, is its unwillingness to consider the reality of institutions above the scale of the individual, but below the scale of the collectivity (usually the nation, or whatever organization is vested with administrative and legislative authority). Many important cross-scale theoretical questions become reduced to micro-vs.-macro, individual-vs.-society, or individual-vs.-group: everything is concerned with just two levels of organization. In Elster's formulation, for example, there are three forms of interdependence that may lead to strategic action:

1. The rewards of each depend on the rewards of all;
2. The rewards of each depend on the choice of all;
3. The choice of each depends on the choice of all.

This leaves aside the issue of whether each and all are an appropriate dichotomy. It may be that the each-vs.-all formulation makes strategic action problems more analytically tractable (see Klir's typology of complexity issues above). More interesting problems come when at least three scales are involved. Individual behavior is described by a case study (thick description), and macro behavior is described statistically by some sort of summing up relationship, but the in-between, indeterminate, path dependent behavior is left out of the picture.

Searching for *the* optimal scale of management would be fine if ecological problems could be handled one at a time. Ecosystems are connected across scales, however, so this is not possible. Different management scales have different attributes to recommend them, however, and so most ecologists recommend a nested approach. Certainly some issues can best be handled by a team of international experts, while other demand a more local approach.

Cross-scale Management or Nested Scales

Levin et al. (1998) note that resilient ecosystems are typified by a hierarchy of responses to perturbations (see Table 7). To quote, "The critical features are a hierarchy of feedback mechanisms; the maintenance of diversity; options for selection to act upon; and the coupling of stimulus and response in terms of space, time, and organizational scales. These are necessary conditions, but do not guarantee success" (p. 229). The authors neglect a range of other ecosystem effects, including the hierarchy of hydrological systems, interactions among organisms both within and across populations, meso-scale processes like fire regimes, flooding patterns, storm paths, and the responses of the biotic community. Neither do the authors provide a picture of a full hierarchy of responses when going on to apply these ecological lessons to economic systems. They discuss a few levels of response: the international (voluntary) system of treaties and agreements, the national system (with the possibility of government action to change incentives or to regulate), and the individual. "Local" actions are identified with unilateral national actions in the face of failed international cooperation (p. 232). In general, they leave out important meso-scale social phenomena at the level of families, communities, and regions.

Table 7. Hierarchical ecosystem responses to perturbation

Level	Type of response	Time scale
Individual	behavioral or physiological	Fast
Population size	reduced reproduction or death	Lifespan
Population genetics	natural selection	Generations

Source: Levin et al. 1998:229

Nested systems

Commonly suggested by writers who have begun to digest the science of hierarchy theory is that an adaptive system for ecological management would be a hierarchy of nested systems, with responsibility delegated to the appropriate level. This begs the question of who decides which responsibilities to delegate (see next section).

There has been a recent move to devolve responsibility (often without resources) to local communities. This has been recognized as more complex than was thought at first. Local communities exhibit the problems described above, some of which are *because* they are local, and others of which they share with other organizations in the social hierarchy. Given that there has been a secular move to favor "local communities," the question must be raised, "what next?" Where will the national governments and other international organizations decide to vest environmental responsibilities? Is it possible to design the optimal set of nested institutions envisioned for management?

Science by Consensus

Frampton (1996) points out the necessity, in the face of ecosystem management "messiness," for including key stakeholders and developing a common understanding or agreement. For Frampton, "the forging of a common set of goals is inherently a "political," that is, a community process."

Paul Richards has advocated a "people's science" as an antidote to the excessively centralized and generalized bureaucratic science informing land-use and ecological policy, particularly in the context of hazard management (Richards 1983). Such an approach has the benefit not just of enlightening and particularizing policy, but of empowering previously neglected and oppressed stakeholders in the political

arena and strengthening their existing capacity for responding to natural disasters (Watts 1983, Richards 1983).

Interestingly, for Richards, natural disaster research and policy is particularly amenable to community perspectives because it is ad-hoc, provisional, and methodologically inexact. These properties provide an entrée for participation by affected communities and for political challenges to the assumptions on which the research is based (p. 49). This is equivalent to a weakening of top-down control mechanisms in a dominant intellectual hierarchy, leveling long-standing structures and providing a window of opportunity for novelty and innovation (a Box 3-type process).[40] In this case, new combinations arise from existing ideas and technologies practiced in a local context as they collide with and challenge weakened prescriptions from centralized bureaucracies and expert consultancies.

Richards is intentionally ambiguous about the exact nature of the relevant hazard or crisis, especially because he doubts the possibility of objective definitions. Elsewhere he has described the socially-constructed nature of environmental crises (see below).

As Lee (1993) notes, most environmental choices entail potential conflict, because they involve redistribution of rights and opportunities. Institutional change with respect to environmental resources frequently arises as those impacted by negative externalities demand compensation for losses incurred. The fundamental lack of fit in this case is between agency and impact, between those who benefit and those who bear the cost. The way in which the potential conflict plays out may depend on other institutions in society for dealing with conflict.

Lee's other fundamental factor leading to conflict is uncertainty: the properties and behavior of natural systems are not well-understood. Part of this is inherent in the complexity of the ecological world, and part is due to the lack of fit between monitoring institutions and the resources they seek to understand, as when political boundaries cut across natural ecological boundaries such as watersheds. Further, data are scarce and difficult to interpret—it may be impossible to choose between competing hypotheses which have starkly different management implications (Wilson et al. 1990). When such a situation obtains, there

is a great deal of room for human conflict: the battle over conceptual models may assume a strategic role, and the "obfuscation and repression of knowledge" may become a source of political advantage (Lindblom 1990, Holling and Sanderson 1996).

Scale and Scope Mismatches

Moreover, while nested, harmonious, systems are the "ideal" prescription for ecological management, with each organizational level corresponding to the scale of important emergent ecological properties, in the real world there are whole levels missing, particularly for meso-level institutions. Governments dismantle existing, competing forms of governance, and NGOs have never had them.

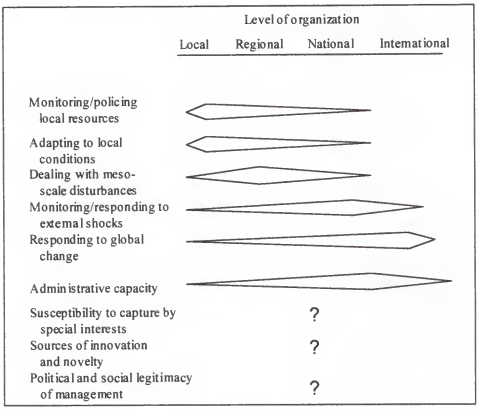

Figure 13. Scale-varying properties of management systems.

[40] This describes for an intellectual hierarchy the same process described earlier for an economic hierarchy; the example given was environmental change overturning existing economic strategies and relations along a tributary of the Amazon (Oliver Coomes, personal communication).

Figure 13 addresses part of the scale problem in resource management. Effective ecological management calls for the ability to monitor local resource use and conditions, to understand and respond to meso-scale processes (fire, floods, soil erosion, etc.) and to respond to global-scale changes that may be occurring over long time scales. Clearly, no single management system would be able to do this. In any given setting, the administrative and legal capacity to effect ecological change will differ, but the figure shows what may be considered the typical situation. Bureaucratic, legislative, enforcement, and taxation authority is vested chiefly in the nation-state—precisely the scale of least importance for interacting with natural systems. Capacity at the local level for creating formal management systems is typically low, as is the capacity at international levels. For this reason, the vast literature on self-organization and spontaneous institutional change and formation (and the attendant opportunities and constraints) is valuable for understanding ecological management. But many scalar properties of social and political systems are not easily (or necessarily) amenable to generalization. To make inferences about what levels of social organizations are most or least vulnerable to capture by special interests, hold the highest degree of legitimacy for regulated actors, or offer the promise of novel or innovative answers to ecological problems, is impossible without delving deeply into cases and their histories (Sanderson and Pritchard 1993).

When multiple hierarchies interact, there can be significant irregularities when the scales do not match. This is true both for social systems interacting with natural systems at inappropriate scales, and for social systems in their coordination with each other. As an example of the first, Sanderson noted that the promise of adaptive management deriving from the comparison of several large-scale ecosystem cases (Gunderson et al. 1995a) may not be valid for small or developing countries. In the cases under consideration, the spatial scale of management units was comparable to, or larger than, many of the world's smaller countries. For example, the Great Lakes Basin Ecosystem would rank above the thirty-sixth largest nation in the world by size, while the Everglades is one-quarter the size of Costa Rica (Sanderson 1995). The success of initiatives in these areas derived partly from the comprehensiveness of managing large, contiguous areas, and partly from the administrative capacity of the bureaucracies overseeing them. With regard to social-scalar interactions, the growth of the NGO movement must be

noted: a recent survey has found that in terms of annual spending, NGOs (in sum) would rank eighth among nations (Briscoe 1998), yet it is unclear where NGOs fit in any traditional hierarchy of social or political organizations (Pritchard and Richards 1997). International environmental NGOs are a particular theoretical condundrum in scalar terms, because of the way they juxtapose global value systems with very local management systems, and do so in a direct way, often without mediation by national-level institutions (Anna Tsing, personal communication).

Where management systems interact across levels of organization, the varied local forms that are (supposedly) adapted to heterogeneous local conditions may restrain the level of possible cooperation. Again, the very strengths of localities and centralized authorities are in general in opposition to each other. If developing countries are "institutionally more heterogeneous than their developed counterparts" (Sanderson 1995), it can be assumed that at least part of the diversity is due to qualitatively different environments and resources. A variety of locally-adapted systems creates administrative nightmares for centralized bureaucracies, where one expects the values of standardization and generalization to be pre-eminent (Richards 1983, Jasanoff and Wynne 1998).

Where there are multiple hierarchies that touch on ecological management, not all have ecological management as their mandate. Some bureaucracies will touch ecological systems only peripherally, and only at some scales. Ecological problem solving becomes a struggle to focus attention on a particular problem, to create an epistemic community (Haas 1990) to meet the exigencies of a particular crisis.

Open Systems

Part of the problem, suggest Peet and Watts (1996) is overly "cybernetic" thinking about systems of environmental governance, which is undermined by the openness of the relevant systems. They are nested in larger entities that can hardly be called "systems." This is one of the greatest frustrations for ecologists and particularly economists, who delight to hypothesize a socially rational planner. In general, proposed solutions for dealing with open systems are to close the system, to provide stronger feedbacks, and to increase knowledge in the system.

Precautionary principle

One of the fundamental formulations of ecological economics has been to advocate the *precautionary principle*: "Do not emit a substance unless you have proof that it will do no harm to the environment" (Leggett 1990). This is a clear expression of a respect for the status quo over and against the ignorance of future change.

Perrings (1991) has offered a qualitative formalization of the precautionary principle in terms of the degree and significance attached by decision-makers to surprising and potentially harmful outcomes. Where decision-makers are able to postulate a probability distribution and cost function for environmental outcomes, the typical calculus of utility maximization under uncertainty is expected to apply. Where outcomes are unfamiliar and potentially surprising, decision-makers would find it optimal to be cautious—to commit resources (or to forgo benefits) in order to minimize future disastrous consequences. Perrings makes it clear, however, that all such decisions will be inherently subjective (although there may be convergence of the opinions of decision-makers[41]). Where the costs and benefits of caution are unequally distributed, this makes the call for application of the precautionary principle in the arena of environmental management necessarily political—and, given the economic concreteness of the costs (or benefits foregone), it makes calls for the precautionary principle necessarily vulnerable to attack.

Milon and Boggess (1988) note that, relative to market outcomes, centralized regulators are less likely to make Type I errors (not regulating when it is optimal to regulate) and more likely to make Type II errors (regulating when it is inappropriate). The precautionary principle is, in essence, a choice mechanism that favors assurance of reliability over assurance of efficiency. As such, reliability theory suggests that there are clear gains from moving certain decisions from the market into the political or bureaucratic arena. Nevertheless, there are costs associated with Type II errors; along these lines, Wiener recognizes the risks due to inaction and action by regulators. He describes the tradeoff as between "market externalities" and "regulatory externalities" (after Wolf 1988). According to Milon and Boggess,

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[41] Although, for reasons given in the preceding chapter it may be unwise to trust such a consensus.

rejecting a regulatory approach "would require that decentralized decisions improve on the Type II error rate to a sufficient degree to offset higher Type I errors."

The precautionary principle stands as a sort of halfway house between consequentialist and deontological prescriptions for action. It is clearly outcome-oriented, in its explicit goal of avoiding worst-case scenarios, while maintaining the option of acting in the future when more information is available. Yet at the same time it embraces the inability to deliver optimized outcomes, prescribing instead an "interim" process while future outcomes remain shrouded in uncertainty. Perhaps it is for this reason, and because robust support requires either consequentialist or deontologial reasoning, that the precautionary principle is so little applied in the real world.[42]

Avoiding functionalism

How does one avoid a naïve functionalism with respect to cultural practices that have an environmental effect? Is it possible to tease apart those aspects of institutions that are purposive and active from those that are merely responses to environmental constraints? It will not be expected that the same balance between purpose and response obtains in every environmental context.

Take for example the practice of field scattering; in some contexts this may be a risk management strategy, whereas in other situations field scattering may be merely the result of a constrained land market under conditions of multiple inheritance (McCloskey 1991, Goland 1993). Practices which are considered to be conservation-related must be shown to be more than a response to increasing scarcity. Relaxation of hunting pressure on a particular species when it becomes depleted can be predicted from a downward-sloping demand curve (as the implicit price goes up, less of the resource is consumed). Is that conservation? A stronger proof of conservation is the demonstration that consumers undertake costly actions (in excess of higher extraction cost) to augment or protect the condition of the resource. While some taboos have conservation implications, that is not true for all taboos (Hames 1991), and concepts for distinguishing them are necessary. Where are they materially adaptive, and where are they part of

[42] It could be argued that in many cases where social decision-making is described positively as an instances of the precautionary principle that there are other constraints on economic activity, so that a "precautionary" characterization is both post-hoc and inaccurate.

ideational systems (Douglas 1992)? For example, when scarce resources become suddenly abundant, are there rules for how to relax taboos? Under what circumstances does such a rule-about-rules arise?

Richards, as another example, warned against attributing risk minimization strategies among African peasants to innate environmentalism. Instead, he notes that in the face of state-mandated risk-seeking (planting high-yield, high-risk cash crops in order to garner foreign exchange), peasants may well opt out, pursuing conservative strategies in implicit protest (Richards 1983).

The *availability heuristic* (Tversky and Kahneman 1974) means that attributes of society that promote resilience acquire salience, while those that do not lose salience (Kuran 1995b:254). It becomes difficult *post hoc* to make useful distinctions, since they require the use of generally unavailable counterfactuals. Part of the difficulty lies in the (often) happy coincidence of the public good with individual good. The prisoner's dilemma has been attractive since cooperation is notable; it entails individual sacrifice. It is much harder to demonstrate the environmental motivation for institutions that entail individual benefit.

Viewing environmental institutions as existing *for the purpose* of solving environmental problems leads to the dangers of functionalism. It relies on a presumed homogeneity of agents, and pays insufficient attention to power differentials within communities. A more skeptical approach (and frequently more cynical) is to view institutions as expressions of political economy, negotiated or imposed solutions to social conflicts, and to ask whether they might have environmental benefits as a side effect.

Politics with a Capital "P": Political Economy of Resilience

The critique of the state in ecological economics rests more on its theoretical and empirical bumbling than on its potential to misuse power or to distort knowledge. State agencies are criticized as rigid, inflexible, and conditioned to ignore surprises from the environment. If state perfidy is broached, it is described only as the most uninteresting kind of greed, self-aggrandizement, corruption and venality. But such defects can afflict institutions at any scale, and they may apply to firms, NGOs, and families as much as to government. It is clear that ecological economics needs to address political issues in a richer way. It can start by asking the questions again which were asked in the previous section: What kind of environmental "crises" lead to what kind of institutional shifts? What can we predict?

Environmental crises may underscore or deepen existing rifts in society, crystallizing them (Richards 1983:54). They may create opportunity for dominant classes to consolidate control over resources (Leach and Mearns 1996), or for the state to build political support for intervention (Scoones 1996). They may create opportunities for economic reorganization (rinderpest wipes out savings in terms of cattle—but some social structures remain intact, see Richards 1983:17). They may level wealth differentials (as with rinderpest), challenge social stereotypes by attacking rich and poor alike (as with smallpox), or raise consciousness among affected minorities (as with cholera, which in 1832 became a focus of radical struggles in Britain) (Richards 1983:17). Richards claims that "epidemiology is not simply a disinterested scientific study but the site of bitter struggles to establish and control paradigms of explanation and to establish a sense of order and meaning to cover personally and socially traumatic events" (1983:17).

They may challenge fundamentally held beliefs, providing opportunity for reorganization and innovation (or alternately, causing a crisis of meaning). This can be connected to Kuran's unthinkable versus unthought—a crisis of meaning will come when there are no longer alternative explanations, even among an oppressed minority.

Homogeneity of Actors

One of the key ways in which political discourse will enrich ecological economics is by challenging the implicit assumption of homogeneity of actors. In much of ecological economics, there is no sense in which differential distribution of benefits matters, because *everyone* benefits from better ecological management (which is to say that *everyone* is the same) (Knight 1992). Such homogeneity does not allow the discussion of differences between interest groups, whether defined in terms of social class, economic sector, or on an issue basis. If there is no differentiation, then there are no political issues.

For example, Levin et al. (1998) discuss the role of markets, the state, and civil society (although they do not use the term civil society, they talk about "trust" as an alternative to market-led or government-led ecological management). Yet all of these organizational modalities express fundamentally symmetrical relations between agents. Their market depends on anonymity (and, perhaps implicitly, equality),

government depends implicitly on fairness (and is treated in any case as a disembodied benevolent third-party), and trust is described chiefly in terms of reciprocal altruism.

Neither in discussing international relations and treaty formation do Levin et al. consider the role of differences between nations in terms of any of the forms of power that could be brought to bear in negotiations. Failure to reach agreements is attributed to a public goods problem where there is a temptation to free ride, rather than to strategic obstruction by a few countries. "[I]nternational cooperation is...hard to sustain...for problems like global climate change where the benefits of, say, a stabilization of atmospheric concentrations of greenhouse gases would be shared by *all* nations and where the costs of effecting such a stabilization would be high for *each* nation" [italics mine].

The cure for such unwarranted assumptions of homogeneity is an explicit focus on distributional outcomes of environmental management policies.

Distribution

As a rather direct response to what he considered the functionalist bent in writing on institutions, Jack Knight's *Institutions and social conflict* posits a distributional conflict as the root cause of institutional change: "Rather than conceiving of social institutions as the product of efforts to constrain social actors as a collectivity, *social institutions are conceived of as a product of the efforts of some to constrain the actions of others with whom they interact*" (Knight 1992:19, italics in original). Knight is clear that institutions can take many forms, and for him, efficiency is not the subject of interest, but rather the social mechanisms by which one institution comes to be established over other possible forms. There are multiple "equilibria" in social institutions. They may not differ in collective benefits as much as they do in distribution of those benefits. Collective benefits come from coordination, but the distribution of benefits is influenced by the form of coordination. Examples include industrial standardization, property rights (many efficient forms), family organization, firm structure, etc. Explanations must account for the exact

form chosen, when many will provide some benefit. While establishing the *possibility* of path dependence was the goal of Brian Arthur, this real puzzle of path dependence is in the selection of alternatives.[43]

Knight points out the problem with social efficiency arguments: distributional conflicts are widespread, and what minimizes transaction costs for an individual may not do so for the rest of society. Knight's point: "Self-interested actors will prefer socially inefficient institutional rules if those rules give them greater individual utility" (pp. 33-34). There is a clear paradox between individual and collective benefits of institutions, and there is no *a priori* reason to assume that an institution, simply because it is a property of a *group*, exists to resolve that paradox.

As the next section will show, where distributional issues are at stake, it becomes important to consider issues of power.

Power

Where bargaining power is a function of wealth, then what is at stake in a distributional struggle is not just a set of current benefits but the ability to control institutional development (and therefore distribution) over the longer run. A simple example will illustrate the process. To use the analogy of a Polya process from a previous chapter, consider a case where the outcome of a repeated game over the division of benefits is probabilistic, with the probabilities of winning corresponding to accumulated benefits. If actors start with equal playing power, then each iteration will rule out certain points on the long-run welfare frontier.

The example given in Figure 14 happened to end with a fairly equal division of wealth. However, with the specified game the outcome is completely indeterminate *a priori*. Just as in the standard Polya process, any point on the utility frontier is a possible outcome as seen from before the repeated game begins (see Figure 15). However, each step of the game reduces the area of future potentially Pareto-safe moves, as seen in Figure 14. Thus, although no one is hurt on any play of the game (no one loses resources), certain ending distributions are ruled out at each step. Based on a similar observation, Hardin (1984), noted that

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[43] In the words of Lance Gunderson, "When there are many alternatives, which way does the invisible hand point?"

even Pareto-safe moves may be blocked by parties who will refuse to bargain or play the game. Why? Because with a limited resource base, even if I am not currently harmed by a move (or even if the outcome of the move can be characterized as "win-win"), my maximum payoff may be reduced. If I had any expectation of achieving my maximum payoff, then an encroachment on that maximum may entail a loss of utility. For the probabilistic game, ruling out feasible payoffs is a clear concern, but even for a strategic game with bargaining, the loss of feasible payoffs may reduce my bargaining power in the future.

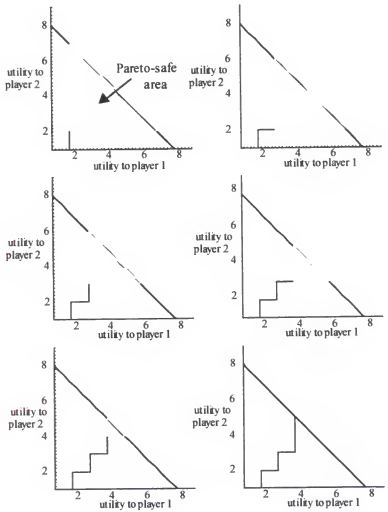

Figure 14. Steps 2-7 of a Polya distribution game. Shaded triangles show Pareto-safe areas remaining after each step.

Loss of (bargaining) power can occur in several ways. If power (to bargain, to coerce, etc.) is a function of wealth, then inequality of payoffs is a concern even when both parties gain, because the balance of power will be slowly shifting, and that will have consequences for future games. How might wealth contribute to bargaining power? Clearly, powers of coercion are dependent on resources (Elster 1989). But even in completely voluntary situations, wealth can change power in two ways. Wealth can be used to learn (privately) about the resource system being bargained over, and the resulting asymmetry of knowledge will put the other party at a disadvantage. If I know my opponent to have an advantage in knowledge and in "bargaining savvy," I may fear the "winner's curse"—that any offer I make (in relative ignorance) that is accepted by my more knowledgeable opponent is likely to be a bad deal (Thaler 1988).

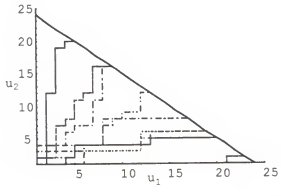

Figure 15. Ten realizations of a Polya 25-step distribution game

Consider instead a more traditional problem of distribution: the well-worked out results of the Rubinstein-Shåhl bargaining model (Varian 1992:276-278). In this case, two players are given the task of dividing a sum (say, one dollar) between them, and they are given a set period of time to reach an agreement. The players are permitted to make offers to each other on alternating days (A gets to make the last offer, B get to make the next to last offer). If they fail to reach an agreement, they each get nothing. Since A and B are rational, and since they know each others' decision processes, by working backwards they have enough information to reach an acceptable division on the first offer.

If A and B have different discount rates, and they know each others' discount rates, the game has a single solution equilibrium for any set of discount rates and for any allowed period of time. If the game is allowed to go to infinity, the shares of the payoff are

$$\text{A's payoff} = \frac{1-\beta}{1-\alpha\beta}$$

$$\text{B's payoff} = \frac{\beta(1-\alpha)}{1-\alpha\beta}$$

Having a discount rate close to 1 denotes patience, and in this bargaining game, patience has its work in increasing payoff. That is to say

$$\frac{\partial(\text{A's payoff})}{\partial\alpha} = \partial_{\alpha}\left(\frac{1-\beta}{1-\alpha\beta}\right) = \frac{\beta(1-\beta)}{(1-\alpha\beta)^2},$$

which is necessarily positive since β is positive. Suppose that A's discount rate is 0.99 and B's discount rate is 0.95. A's share in the payoff would be 84 percent against B's 16 percent. B's impatience has a cost in her bargaining power.

If the two players play again, the result will be repeated. However, in a real interaction, it is reasonable to assume that there will be a wealth effect on the effective discount rates of the players. If A's increased wealth makes him more patient than B's wealth makes her, the A's bargaining power will have increased in the next round. B will be very reticent to reach any agreement that increases A's bargaining power, especially as A's discount rate approaches 1, when the payoff ratio turns sharply in A's favor. The exact results will now be dependent on the relative rates of increase of discount rates with wealth; depending on the rates of change, any ultimate distribution could prevail after a large number of rounds. If there is a stochastic element to the payoffs, the endogenized discount rates could easily result in multiple equilibrium distributions, making "playing the game" potentially surprising. In strategic terms, as Knight points out (Knight 1992:36), the uncertainty may cause players to opt out, even when there Pareto-gains remaining.

Hierarchies of Power

Power in bargaining situations is clearly not the only way in which power is expressed. For example, power in the Kuranian framework is exercised in several ways—directly, but manipulating the negative payoffs for dissenting, and indirectly by manipulating perceptions of public opinion.

One of the problems that pertains to nested institutions is that political interests (whether class-based or other) are probably not distributed evenly *across* scales in any hierarchy. If a distribution of management responsibilities across scales would preclude significant reorganization at a later time, then even quite substantial social benefits at the present time may not be enough to gain cross-cutting commitment to such an institution (for the general argument see Knight 1992). Further, the consequences of power interactions within a social hierarchy may vitiate the desirability of nested systems in terms of effectiveness and legitimacy. If there is a potential the interaction across levels, then the question of optimizing management responsibilities across levels becomes more difficult. For example, local systems may function better by going their own way, keeping government at bay (Sanderson 1995), than they would having gained the imprimatur and cooperation of the state.

While noting the value of a diversity of responses available across hierarchical levels, Levin et al. (1998) fail to note that distributional concerns at lower levels may be misrepresented or betrayed at higher levels in a social hierarchy, or to note that a heterogeneity of concerns at local levels may result in the inability of higher levels to reach multilateral agreements.

If it was ever thought that power in a hierarchy was only a top-down phenomenon, except for brief overturns and upsets accompanying revolutions, then this preconception must surely be adjusted to match one of the main currents of the late twentieth century. Local is in, with development agencies, NGOs, and even governments who are pushed to decentralize. The recent movement to empower local communities is built on many foundations, including mistrust of the nation-state, respect for traditional lifestyles in the context of conservation movements, and the spread of democracy (Agrawal 1997). Part of the argument for devolution of power to localities amounted to claims for the ecological superiority of indigenous management systems, a notion Kent Redford called "the ecologically noble savage" argument (Redford 1990). Richards critiques the notion of ecological adaptation as a "paradigm of explanation" in human

and cultural ecology. His complaints are three: that it is used too broadly, applied as it is to merely enduring features of local communities; that it is inappropriately organicist, overemphasizing the corporate nature of communities and ignoring internal competition; and that it is overly static, assuming that societies are "in equilibrium with their environment" (Richards 1983:14).[44]

Although community-based conservation has led much of the recent rhetoric about shifting power to local people, it borrows from another historic strand in political discourse: populism.

Populism and democracy

> "To throw some light on discussions about 'the people' and 'the popular', one need only to bear in mind that the 'people' or 'the popular' . . . is first of all one of those things at stake in the struggle between intellectuals"
>
> (Bourdieu 1990)

According to Peet and Watts (1996), both development and anti-development thinking looks to *the people* for legitimation and vision. Populism permeates the dialogue of the 1990s. They offer the following characterization: Populism is "based on the following major premiss: *virtue resides in the simple people, who are in the overwhelming majority, and in their collective traditions*" (Wiles 1969: 166, original emphasis, cited in Peet and Watts 1996:26). Populism is useful, and flexible, as an ideology. Macrae (1969) calls it apolitical—a condition which marks its mythology more than its use. Political questions remain about who "the people" are, how identity is constructed, and what criteria for inclusion are, but these are rarely addressed except at the margins of populist discourse (Mackey 1997).

Michael Watts (1983) categorizes much of the emphasis on small-farmer adaptation in human ecology under the label "populist." In his critique of a representative piece of literature he claims: "Implicit in … [the] discussion of farming communities is a type of consensus that farmers are decentralized socialists at heart, regulated by ecological values and motivated by aspirations to return to a natural economy." In Watts' view, what undoes the human ecological analysis (aside from obvious "Panglossian" excesses) is the neglect of differentiation and social relations within communities of resource managers. While many human and cultural ecologists are keen to point out the diversity of conservation and risk management

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[44] Yet Richards himself has been accused of over-generalizing the adaptive agriculture of the "African

practices, they are less keen to acknowledge the social, political, and economic inequalities within communities that temper the attractive qualities of environmentally-adaptive institutions.

The results of the previous chapter indicate clearly that appeal to *the people* can have very different results depending on the structure of their social networks and organization. The ideas and values and preferences of the people depend on social context, and on how that social context is interrogated, as seen in the model of overlapping neighborhoods. At the extremes of the spectrum, individuals are dependent on their local neighborhood or on society at large for confirmation, support, and modification of their preferences. Put another way, an appeal to the people does not yield any predictable objective result, because public opinion is a social construction and not just a social statistic.

Multiple hierarchies

I would further suggest that the inability to construct optimally nested systems is due to the multiple hierarchies within which individuals and local communities are nested. Peet and Watts, for example, note the new social movements are different from older movements, since they are identity-based rather than class-based; this means that radical politics is not so much an assault on a ruling class as on particular instituitons. There is a consequent indeterminism to modern politics, due to the "multiplicity of antagonisms, each tending to create its own space and politicize a specific area of social relations" (Peet and Watts 1996:31). New social movements in the Third World draw their organizational form from a much wider variety of social groups than just trade unions and political parties.[45]

Multiple identities are no bad thing in terms of resisting authority—if it cannot be assumed that hegemonic organizations are in any way beneficent, there are clear advantages to multiple and overlapping alliances and systems of organization. An example is given implicitly in Lansing's discussion of water management on Bali by the water temple system (Lansing 1991). While crop distribution and taxation was controlled by political systems (organized geographically by hilltops), the irrigation system was controlled by a religious cultural system (organized geographically by watersheds). When the Dutch

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farmer" (see critique below by Watts 1983).

seized political control of the island, the agricultural system of wet rice production proved remarkably resilient to the new economic organization. Only in the post-colonial period, with the advent of very intrusive government-mandated Green Revolution technologies, did the agricultural system experience thoroughgoing crisis.

Understanding Uncertainty

Defining risk

Richards (1983:44) poses the problem of the social construction of risk, with respect to reports of famine.[46] Richards is skeptical of reports of famine in Africa going back into the eighteenth century. He raises the issue of food distribution and political economic factors as one source of "famine" other than climatic factors (now commonly recognized as the cause of most famines, see for example the entitlements approach of Sen (1981; reviewed in Ravallion 1997), but he goes further. For Richards, "famine," like "drought," are words used to signify historical upheaval and economic collapse, which may "have nothing to do with climate at all" (1983:45). They are of ideological significance, but do not have concrete material significance. Watts (1983) finds this an exaggeration, but nevertheless recognizes the apocalyptic nature of even scholarly characterizations of drought, famine, desertification, and land degradation.

If the characterization of an environmental situation as a "crisis" depends on the observer, it does not follow that crises (even constructed ones) are arbitrary or meaningless. But it does mean that defining a situation as a crisis can be a political move, that there may be predictable disagreements about the severity or existence of the crisis, and that responses may be as much to address the underlying political and social tensions as they are to relieve immediate suffering or damages. Wholly apart from their (possibly) objective truth, claims about environmental hazards may be found to reveal distributional issues, power relations, and underlying beliefs and mental models.

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[45] It can be argued that a similar reorganization of politics is occurring in the United States, with a diminished substantive role for national political parties (except as fund-raising machines); see "Out of shambles, strength?", *The Economist*, Nov. 7th, 1998.

[46] He quotes the cynical maxim "*Qui se nourrit de la famine en Afrique?*" (literally, "Who is nourished by the famine in Africa?").

One such set of beliefs is about entitlements. Entitlement systems, as defined by Sen (and as described in Richards 1983) are "beliefs, created in political practice, about who ought to get what under what circumstances, and the embodiment of those beliefs in legal and economic process, e.g. land tenure rules, notions of family obligation, wage rates, rules of market transaction etc. *Such standards are contingent and time-bound (they are specific to particular historical circumstances)*" [my italics]. Richards sees famines as the collapse of established entitlement systems. If they are, then quite apart from the prevailing material conditions, the characterization of a famine should reveal a set of (unfulfilled) expectations about rights and access to important resources.

Just as claims about environmental hazards or crises may indicate a challenge to entitlement systems, they may indicate a challenge to fundamentally held scientific or folkloric beliefs about the operation of an ecosystem.

The subjective nature of environmental descriptors also means that, as a social construction, a crisis is susceptible to the kinds of dynamics described by Kuran (see previous chapter). To deny the existence or severity of a massively recognized environmental crisis is to appear cold-hearted, complacent and reactionary, whereas to claim the existence of a crisis that lacks public recognition is the sign of an alarmist or a coward, *regardless of the scientific evidence.* It also means that any claim for an environmental danger or crisis that has public credibility is partly based on hard knowledge and partly based on soft knowledge, and a great deal of political pressure may be brought to bear to capture public opinion based on soft knowledge.

Manipulating risk

To what extent is political ecology "harnessed to a rather outdated view of ecology rooted in stability, resilience, and systems theory " (Peet and Watts 1996:12). How are both the old and the new ecological theories amenable to political manipulation? What kinds of agents find empowerment in which theories?

Worster argues that disequilbria in ecological models can serve as a "cover for legitimating environmental destruction" , but at the same time, its emphasis on fine-scale spatial and temporal contingencies may tend to privilege complex local systems of knowledge.(Peet and Watts 1996).

In the words of David Ludden (personal communication), "governing is what states do." Peet and Watts would argue that in much of the world, what states do is "development," and that the "apparent ability to 'make things better' is *the* main way of achieving power" (Peet and Watts 1996). Richards (1983) is explicit about the role of state agencies using scientific information to manufacture environmental crises, which situation they then exploit to expand their control. Legitimating expanding bureaucracies may take the form of providing expert technical assistance, solving environmental crises, or mediating local disputes over resources, but the result in each case is the same. If local populations are particularly troublesome for bureaucratic states (as, for example, Sahelian nomadic pastoralists are), then one strategy for expanding control is to declare them environmental liabilities (Marnham 1979).

This relates directly to the paradox described above: ecosystem complexity demands sophisticated understanding of spatially heterogeneous and temporally variable systems of people and nature, and developing that understanding points in two directions. Expert bureaucracies may have the resources, technical skill, and broad boundaries to capture this complexity, and local communities have long experience, spatially-explicit knowledge, and critical dependence on the resource base. Because local knowledge is by definition not part of the centralized, standardized system of science, it is easily disparaged or ignored, regardless of its appropriateness or accuracy (Richards 1983:52ff).

The hegemony of centralized science bureaucracy is not completely defined by the dominance of the state; it may also expand into the space provided by a socially constructed ignorance of environmental risk on the part of non-scientists. This dynamic was described for radiation workers at the Sellafield nuclear reprocessing plant in the northwest of England and for households whose homes were being monitored for radon (Wynne et al. 1990). In each case, agents chose to ignore the technical details underlying descriptions of environmental risk, because of their collaboration with "scientific experts," despite the fact that their "interests" lie in understanding the dangers surrounding them. An active role in the scientific enterprise would have been psychologically disturbing (because of the magnitude of the danger) and socially disruptive (because of the existing intellectual division of labor). The relationship between workers, households, and scientific bureaucracy were far from agreeable, but the disagreements revolved around social issues of power and trust rather than scientific detail (Jasanoff and Wynne 1998).

Conclusions

Paul Richards argued that natural disasters opened a window of opportunity for new voices to be heard, by making it clear that disaster and crisis theories were tenuous, ad hoc, and provisional. The new ecology has already shown itself to have a similar dynamic: where received wisdom on ecological management was wedded to old ecological views, revisionism has led to the fall of orthodoxy. The danger is that it may be replaced with another orthodoxy maintained with no less hubris than the old. The new orthodoxy may have as its only goal the systematic debunking of all theoretical constructs as mere power plays (Batterbury et al. 1997).

It must be possible to move forward in understanding the relationship between people and nature with careful and humble theorizing, admittedly modeling a partial picture, without succumbing to the temptation to overreach. I have addressed a number of partial models in this chapter, and discussed how they have been informed and challenged by the new ecology, but they are only a starting point. A few instructive lessons have been learned.

Ignoring or suppressing some notion of what is political has political ramifications itself. Politics is not simply, or even mainly, about base and corrupt public manifestations of private greed, nor is it simply about the "authoritative allocation of values" (Easton 1981) as an alternative to the market. Politics is worthy of intellectual attention on its own terms.

The politics of natural resource management has been, and will remain, messy, incomplete, inharmonious and fractured. Simple prescriptions that subsume politics under populist rhetoric such as citizen science or community-based resource management will miss the requisite complexity for understanding hierarchies of power.

There are no guarantees of fit between ecosystems and institutions, no promise of perpetual harmony if institutional design is careful enough (Gunderson et al. 1995b). Both ecosystems and institutions evolve under multiple hierarchies that pull them in different directions at various times in their development, and there is no overarching end toward which these systems self-organize.

CONCLUSIONS

New insights in ecology have effects on the social sciences in several ways. One way is methodological: the study of complexity in ecosystems provides a window on the issues of path dependence, indeterminacy, multiple equilibria, and scales that illuminates them in ways that are impossible by relying on mathematical theory or examples from the physical sciences. Many ecosystem processes occur on scales which are comprehensible to humans; we can walk around in a forest or a swamp, or snorkel in a coral reef, and in so doing we can integrate a wide enough range of scales to understand something of the ecological hierarchies of the last chapter. Because they are living systems, they capture our imagination, and we find it easy to envision the interplay of historical and spatial contingency. The lessons learned there may then be cautiously applied to other complex adaptive systems, such as economies or political systems. Overzealous mapping of ecosystem dynamics to social dynamics is easily found, but the useful differences uncovered serve to sharpen theories in both realms. Some models will be found to be general, others will highlight processes that occur in social systems but not in ecosystems, and vice versa. But a flowering of theory in one field may be expected to have spillover effects in other disciplines, even when the subject matter is quite different.

The effect of new ecology on the substance of economics and political science is through a revision of the effects of ecological management. Simple models of environmental interactions that treat the environment as a backdrop to human affairs are found wanting; in a reflexive fashion, the new view of nature changes the way in which nature is managed.

The effect of the new ecology and its inherent revisionism on political imagination will be twofold. First, it can certainly cause interested parties to doubt the validity of received wisdom—to realize that existing models of resource use and impact may be held in place long after their invalidity has been established, and that the misapplication may have its roots in political or bureaucratic interests. Second, it can cause actors to mistrust *all* models and worldviews, to reduce all attempts to explain the world to

power plays on behalf on privileged (or unprivileged) groups. Such a view would consider all ecological knowledge soft. If, however, the new ecology introduces a healthy skepticism into the way ecological models are constructed, promoted, and received, then the soft component of knowledge may be challenged more easily, and more recourse will be made to good science.

Cycles of Salience

One of the lessons of moderately complex views of the world is that existing models may be both partial pictures of reality and occasionally valid. This is stronger than the observation that even a stopped watch is right twice a day. It amounts to a claim that the same system must be described by different models at different points in its history, because controlling forces have shifted as the systems dynamics have changed. Theories of the mid-range become more important than grand theory, because they describe actual systems, and yet seemingly irreconcilable models may be shown to govern a system at different times.

Economists in particular must learn the lessons of modeling multiple hierarchies. Variables change at different rates in different systems, and at some time scale *everything* is endogenous. Furthermore, the characteristic rates may change over time, so that variables that appeared constant may begin to change more suddenly as the system undergoes structural change. Public opinion, for example, may change only slowly and gradually (or not at all) for most of the time, and then suddenly flip.

Role of History

Respect for precedence in judicial and administrative settings, a form of rigidity, has been interpreted by Heiner and others, (Heiner 1986, Milon and Boggess 1988) as a concession to reliability over efficiency as a choice criterion. To depart from historical precedent would require demonstration that the flexibility adds reliability to the already known results from past history. Respect for history thus gives society assurance of reliability. But it also allows the reinforcment and entrenchment of tradition, even in situations where it applicability may be questioned on efficiency grounds (as when expert bureaucracies come into conflict with community practices, e.g. Richards 1983).

Sanderson (1995) notes the role of history in "decision-making burdened by memory." "Knowledge influences decision-making, but always makes its way to policy through such mediations as memory and ideology" (p. 388). This recognition insures that cultural filters (even for "hard" knowledge) are not ignored and that experience is considered as one of the driving forces behind knowledge formation (and that the experiences of different actors may be differently perceived). Inasmuch as memories and ideology are social rather than individual attributes, they are susceptible to the kinds of dynamics Kuran specified. Memories (and ideology) have an individual component as well—therefore their formation and endurance owes much to the sequence of payoffs for conservatism and flexibility that Heiner discussed (and where the determining events are probabilistic, there is at least the potential for differentiation among agents). In both regards, it would behoove us to talk about the past in terms of "histories" rather than a monolithic "history."

If successful management regimes are able to suppress rare events, it was noted above that "active forgetting" may be adaptive. Actions appropriate for the now-less-frequent events are less reliable, and may be dropped from the repertoire. Certainly, Kuran's theory about the evolution from the "unthinkable" to the "unthought" implies that it only takes a generation to forget unexpressed (i.e. unused) beliefs. The same dynamic (cross-generational forgetting) no doubt applies to ecological knowledge if it is unused. This supplies one reason why we can describe human perception as scale-bound. In the United States we frequently hear hurricane and civil defense experts warning about the lack of hurricane preparedness for recently arrived populations that have never experienced a major storm. Recall the threshold condition for including an action in an agent's repertoire:

$$\rho_d \equiv \frac{r_d}{w_d} > \frac{l_d}{g_d} \cdot \frac{1-p_d}{p_d} \equiv T_d$$

Lack of experience with a rare event may lower an agent's estimate of the gain from preparedness (g_d), and it may cause them to discount the probability of occurrence (p_d). Both of these effects will raise the threshold of tolerance, making it less likely that they will retain the action for preparation. It might be considered irrational to ignore the lessons of history, particularly the cumulative probability distribution of

disasters. This depends on the learning model attributed to the decision maker; when the environment is changing, it makes sense to discount the past.

But this ignores the role of population heterogeneity. Much of the writing on small-scale traditional ecological knowledge focuses on the role of wise men, stewards, and senior hunter and fishers, who it is assumed have a higher reliability for rare actions than the population at large, who can be relied upon in dire (and rare) circumstances for wisdom and advice. This is certainly in accord with suggestions from Heiner that surprises from the environment will cause agents to doubt the comprehensiveness of their repertoire of responses and to desire to learn new behaviors. Heiner leaves unspecified the details of the behavior acquisition process—but using as a heuristic the Holling "adaptive cycle" diagram, we would assume that this is a Box 3-4 process, and that as such, learning in a crisis may be extremely vulnerable to outside driving forces. It is precisely at these junctures that political control over memory, knowledge, and innovation are the most important, because it is at this time that they will have the most effect on the structure of institutions.

The Revival of Narrative

Rather than directly criticize the issue of rational choice, some authors have recommended parallel means of discourse about economic issues. Kiser discusses the revival of narrative in historical sociology, but his review and critique resound with developments in other disciplines (Kiser 1996, McCloskey 1983, Zald 1996). A similar method of "storytelling" is Nelson and Winter's "appreciative theorizing" (Nelson 1994, Nelson and Winter 1982). One source of these stories is in institutional history; examples include Parish and Michelson (1996) for political path dependence despite market reforms, Putnam (*Making Democracy Work*) for Italian institutional path dependence (but see Sabetti 1996 for an alternative view).

Because instances of path dependence are of a historical nature, they lend themselves to storytelling, in the post-modern sense. But if nature is fundamentally unpredictable (as strong path dependence would imply), this is the end of theory, and storytelling is all there is.

Kiser reminds us that elucidating "deep structure" means not telling the whole story about a particular system; scientists should use theory to draw out their story, rather than take a raw empirical approach. Just

as bad as using no theory, in Kiser's view, is to use "all the theories," regarding theory as as a "toolbox" of ideas. Story-tellers need a rationale for saying which theory applies when, based on boundary conditions. It is not enough to say "sometimes people behave this way, and sometimes they behave this way." How do their motivations interact with their environment and with the motivations of others?

The problem is not to say "everything is connected to everything else" or that history matters all the time. The important question is, when does it matter and when not? When is it possible to predict, and when not? When does the order of events matter and when not, and why? Kiser relates this, for the storytellers, to the need for abstract scope or boundary conditions, not historical ones. For example, which aspects of history are important for parliamentary development? Is it that the system in question is in seventeenth-century France or that it was a hereditary monarchy? One condition is portable, the other not (and by implication, one condition is testable and the other not). The goal is to highlight deviations from theoretical structure, searching for revealing anomalies.

Too infrequently is the question asked, what features are historically contingent and what features are general? Krugman (1991b, 1993), for example, has a path-dependent economic geography model similar in some respects to Arthur's, but he is able to use it to show that while there are many equilibrium structures (distributions of manufacturing across n regions), they share similarities (equidistance between agglomerations, an agglomeration shadow around cities, etc.). Unless the argument is being made that everything is historically contingent, useful distinctions need to be drawn (Krugman, 1994).

The next questions that arise for narrativists are, why are some things historically contingent and others not? Are there structuring forces that determine the level of contingency? What are the forces that govern connections across scales of time and space?

North (1993) recommends that the usefulness of rational choice versus boundedly-rational choice be defined with reference to (1) complexity of the problem, (2) completeness of information, (3) frequency of choice and (4) degree of motivation of the players (p. 161). It would be useful to develop a typology of institutions that would evolve in various contexts using these four, and perhaps other, descriptions.

In summary, there are a wide range of recent developments in economic theory (and on the fringes of economic theory) which can contribute to an understanding of human agency at multiple scales in space

and time, but in general these require that traditional assumptions about rational actors and perfect information be (systematically) relaxed, or at least made more sophisticated. Some of this is accomplished by recognizing that the same economic agents play different roles and exhibit different preference structures across scales, and some is accomplished by considering the interactions between economic agents, either through externalities, and attempts to manage those externalities, or through institutions, and their processes of change.

People, Ecosystems, and Resilience

Lastly, we turn to what some commentators have concluded is the most sticky issue raised by the new ecology: the relationship between people and nature. We have seen how different views of (objective) ecosystem dynamics (and implicitly, spatial pattern) can be characterized as different perspectives of the adaptive cycle, therefore all partial truths. Is the same true about the role of people with respect to natural systems? Certainly the implication of the myth of the ecologically noble savage is that some people are part of ecosystems and others are not.

But the question is not all or nothing. Deciding whether society is a part of nature or not may best be left to philosophers; being able to explain why an agent would find it easy to believe one side of the controversy or the other may be more amenable to social science modeling. In any case, there are several considerations in asking questions about ecological resilience and social systems that we would do well to keep separate, and to address them sequentially rather than simultaneously.

The first issue is whether the environments we are dealing with exhibit the properties of the "new ecology." As we have said, contingency is a property of ecosystems at some points in their paths, and not in others. The resilience of an ecosystem to disturbance is not strictly an inherent property, it varies with both internal and external conditions. Sometimes an ecosystem may be vulnerable to flipping into an alternate stability domain, and sometimes not. The object of theory may be not so much to predict, and to suggest when a system is predictable and when it is not.

The second issue is to ask what implications the observed ecosystem properties have for ecological management. This has been the topic of this paper. We can then begin to ask if people are in any sense

managing for ecological resilience, or whether they even could if they wanted to. We may find that in almost every system, other objectives swamp ecological resilience as explanatory variables for human management strategies.

A third issue is whether economic and political systems exhibit any of the same properties (in particular, do they display the properties of the adaptive cycle). Inasmuch as the adaptive cycle is a truism that describes any system that has a life cycle of birth, death, and potential renewal, then they do. Whether social or political systems are *selected for* adaptive cycle dynamics has not been critically addressed.[47]

The final question concerns the joint system. If it is found that ecosystems exhibit complex properties, *and* that people find it worthwhile to manage for ecological resilience, *and* that some of the same dynamics, such as the adaptive cycle, apply to social systems, *then* we are prepared to ask the final question: are social and ecological resilience related to one another in any way? Is one a necessary condition for the other? A sufficient condition? Another way of asking the question is whether ecological resilience is consonant with social resilience. We would certainly not expect the answer to be an unqualified yes, nor would we be willing, given the political considerations and complexities raised in this document, to suppose that "constructing consonance" would necessarily yield happy outcomes, either for ecosystems or for people.[48]

---

[47] With the possible exception of Holling and Sanderson (1996), although the authors jumped back and forth between issues of social dynamics and harmony between social and natural systems.

[48] Although one often hears the same voices that decry the simplistic prescription of "fixing broken markets" advocate simple prescriptions for harmonizing social and natural systems.

APPENDIX A
MATHEMATICA CODE FOR THE STANDARD POLYA PROCESS

The Polya process simulation was implemented in *Mathematica 3.0 for Students*.

```
Polya[n_]:=Module[{initurn, pr,redball, update},
    initurn={1,1};
    pr[urn_]:=urn[[1]] / Apply[Plus, urn];
    redball[pred_]:=Floor[pred+Random[]];

    update[urn_]:=Module[{rb, newurn1, newurn2, newurn},
          rb=redball[pr[urn]];
          newurn1=urn[[1]]+rb;
          newurn2=urn[[2]]+(1-rb);
          newurn={newurn1, newurn2}
    ];

    history=NestList[update, initurn, n]
]
```

The current contents of the urn are defined as the list $urn=\{n_r, n_g\}$, where n_r=*urn*[[1]] is the number of red balls and n_g=*urn*[[2]] is the number of green balls. The code sets the initial composition of the urn to {1, 1}. The total number of balls is given by the function Apply[Plus, urn]. The proportion of red balls (and therefore the probability that the next ball drawn will be red) is given by the function *pr*[*urn*_]. The random function *redball* returns a value of 1 if the next ball drawn is a red ball, and 0 if the ball is green.

The function *update*[*urn*_] draws a ball from the urn, and increments either the red or the green element of *urn* depending on the result. The list *history* applies the *update* function *n* times, and returns a list of the values of *urn* after each draw.

APPENDIX B
MATHEMATICA CODE FOR THE DUAL BELIEF MODEL IN SPACE

The dual preference simulation was implemented in *Mathematica 3.0 for Students*. Two standard add-on packages are necessary to load:

```
<<Statistics`DescriptiveStatistics`
<<Statistics`DataManipulation`
```

Propagation Curve Display

To see a graphical display of a set of thresholds for individuals, it is necessary to create a step function based on the thresholds list. Necessary input is a set of thresholds. For example:

```
thresholds={0,20,20,30,40,50,60,70,80,100};
```

The following function converts the list into a step function:

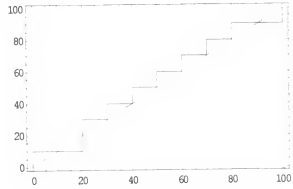
```
propagationCurveSegs[lis__]:=
  Module[{propPoints,x,y},

    propPoints[thres__]:=
     Append[
       Prepend[Transpose[{
             Union[thres],{{
                   Transpose[CumulativeSums[Frequencies[thres]]]
                     \[LeftDoubleBracket]1\[RightDoubleBracket]}
         /Length[thres])*100}], {0,0}], {100,100}];

    x=propPoints[lis];
    y=Prepend[Drop[x, -1], {0,0}];
    Flatten[
     Transpose[
       List[Transpose[
           List[Transpose[x]\[LeftDoubleBracket]1\[RightDoubleBracket],
             Transpose[y]\[LeftDoubleBracket]2\[RightDoubleBracket]]], x]],
     1]
  ]
```

And this function plots the propagation curve:

```
propagationPlot[lis__]:=
  Module[{plot1, plot2},
    plot1=ListPlot[lis,PlotJoined->True, Axes->None, Frame->True,
      AxesLabel -> {"Expected public opposition",
          "Actual public opposition"}];
    plot2=Plot[x, {x,0,100}];
    Show[plot1, plot2];
  ]
```

Finally, the command to plot the curve has the following form:

```
propagationPlot[propagationCurveSegs[thresholds]];
```



Simulation Program

The program takes parameters t (the maximum number of iterations), m (the size of the Moore neighborhoods), and *initrev* (the initial percentage of revolters). The use of the function *FixedPointList* in the updating procedure allows the program to proceed to an equilibrium but with a maximum of t steps.

```
Kuran[t_,m_, initrev_]:=
  Module[{thresholds, initialize, init, GenMoore,localopin, rule,newlat},

    (* this line can be changed to accomodate other distributions. It should
       always be sorted *)
    thresholds =
     Flatten[Map[(10*Table[#, {11}])&, {0, 2,2, 2,3, 4, 5,6 ,7, 8, 10}]];

    (* this line prepends voting element, appends expectation element, *)
      (* randomizes and partitions *)
    initialize[thresmat_]:=
     Partition[
       Transpose[
         Rest[Transpose[
              Sort[Transpose[
                  List[ Table[Random[Real], {Length[thresmat]}],
                    Join[Table[1, {Round[Length[thresmat]*initrev/100]}],
                      Table[0, {
                          Length[thresmat]-
                            Round[Length[thresmat]*initrev/100]}]], thresmat,
                    Table[0, {Length[thresmat]}]]][[1]]]],
       Sqrt[Length[thresmat]]];

    init=initialize[thresholds];

GenMoore[func__, lat_, n_] :=
  MapThread[func, Map[RotateRight[lat, #]&,
       Prepend[
           Delete[Flatten[Outer[List, Range[-n,n], Range[-n,n]], 1],
             Position[
               Flatten[Outer[List, Range[-n,n], Range[-n,n]], 1], {0,0}]], {
```

```
          0,0}]], 2];


    localopin[lis__]:=
     List[First[List[lis]],
       100*N[Mean[
            Transpose[List[lis]]\[LeftDoubleBracket]1
              \[RightDoubleBracket]]]];
    rule[{{a_, thres_, eo_}, expopin_}]:={0, thres, expopin} /;
       expopin < thres;
    rule[{{a_, thres_, eo_}, expopin_}]:={1, thres, expopin} /;
       expopin \[GreaterEqual] thres;

    newlat=FixedPoint[
       Partition[Map[rule, Flatten[GenMoore[localopin, #, m], 1],1],
           Length[init]]& ,init, t]
    ]
```

To generate a random spatial arrangement of the actors and run that arrangement under five Moore neighborhood regimes, the following function was used:

```
KuranDist[seed_, t_, initrev_]:=
   Module[{results, pollResults},
      SeedRandom[seed];
      results=Map[Kuran[t,#,initrev]&, {1,2,3,4,5}];

      pollResults=
       Apply[Plus,
         Partition[
           Transpose[Flatten[results, 2]]\[LeftDoubleBracket]1
             \[RightDoubleBracket], (
               Dimensions[results]\[LeftDoubleBracket]2
                 \[RightDoubleBracket])^2], 2]
      ]
```

The use of the *SeedRandom* function allows particular configurations to be examined in detail later.

To run the previous program for 2000 different random spatial arrangements, the following function was used:

```
Map[KuranDist[#,100,5]&, Range[2000]]
```

The result is a list, sorted by configuration, of the equilibrium number of revolters for each neighborhood size.

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BIOGRAPHICAL SKETCH

Lowell Pritchard Jr. (Rusty) is a Visiting Assistant Professor of Environmental Studies at Emory University, in Atlanta, Georgia. He teaches courses in environmental science and ecological economics. His current research interests are on the institutional dimensions of environmental change, environmental politics, and agent-based modeling. From its inception, he has been a participant in the Resilience Network of the Beijer International Institute for Ecological Economics (funded by the John D. and Catherine T. MacArthur Foundation), and he is on the editorial board of the journal Conservation Ecology.

Previously, he was the Science Officer for Focus 1 of the Land-Use and –Cover Change Project (LUCC) of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions of Global Environmental Change Programme (IHDP), and he was a research associate in the Tropical Conservation and Development Program at the University of Florida. He has worked as an environmental consultant in northeast Florida and was instrumental in starting an environmental restoration and monitoring firm there. He received a B.S. degree from Duke University in zoology while holding an Angier B. Duke Memorial scholarship, and an M.S. degree from University of Florida in environmental engineering sciences (systems ecology) while holding a Beinecke Memorial scholarship. He did post-baccalaureate work at the University of Glasgow in Scotland in the history and philosophy of science on a Rotary International Fellowship.

He enjoys canoeing, snorkeling, hiking, and playing the piano. An avid collector, he has what is believed to be the largest collection of souvenir and decorative backscratchers in the world, with over one hundred and fifty pieces.

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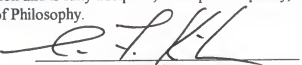

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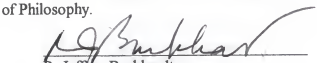

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May 1999

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